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SCOTTISH DEVELOPMENT DEPARTMENT
THE WELSH OFFICE

Roads in urban areas

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Introduction

It is twenty years since the Minister of War Transport appointed a Committee under the chairmanship of Sir Frederick Cook, whose terms of reference were:

> 'To consider the design and layout most appropriate to various types of roads in built-up areas, with due regard to safety, the free flow of traffic, economy and the requirements of town planning, and to make recommendations.'

The Committee's report, embodied in the publication *Design and Layout of Roads in Built-up Areas*,[1] has served as a guide to highway engineers throughout the post-war period.

The past twenty years have seen a growth in population, car ownership and traffic volume far greater than was thought likely at the end of the war. For example, the Committee recommended that in designing new roads, provision should generally be made for a volume of traffic double that of 1939. By 1964 the pre-war figure of vehicle ownership had already more than trebled; by 1970 it will probably have multiplied more than five times and by 1980, eight times.

The Cook Committee recognised the need to design the road system of a town as part of the overall plan for the town as a whole. More recently the Buchanan Report (*Traffic in Towns*)[2] has shown in graphic terms what can happen to living and working conditions in urban areas if this concept of integrated town planning is lost sight of, or not properly understood.

This manual, covering much the same ground as its predecessor, brings into one volume the recommended standards of urban road design and layout which have been developed in the intervening years. It is, however, important to bear in mind that the manual does not purport to give guidance on the planning of future road requirements. It will help highway engineers to achieve good standards of design once conclusions have been reached about the purpose and location of the roads required and the capacity which is needed. The manual does not deal in any detail with the many factors which must be taken into account or the planning processes involved in arriving at such conclusions. These decisions will call for the study and forecasting of land uses and transport requirements in the detail appropriate to the size of the town concerned. Decisions will have to be made as to the balance to be arrived at between the use of public and private transport, and consequential parking and traffic management policies worked out. Above all, the plans will have to be developed in the context of the foreseeable scale of resources which can be devoted to urban road building.

The evolution of a practicable urban road network and its integration with the urban environment is a task demanding the closest collaboration between highway and traffic engineers, architects and town planners. Once the decision has been taken to build or improve a road in a given place, this manual shows how it can be designed to fulfil its stated traffic requirements safely, efficiently and economically.

1 Urban traffic

1.1 Design for safety and capacity

1.1.1 Urban roads and development

Urban roads should be designed to be safe and to permit the free flow of traffic at reasonable speed. Their traffic capacity should be balanced against the traffic requirements of the existing and proposed development they are expected to serve. This will necessitate the planning of the urban road network as a whole, and will involve forecasting future traffic volumes and appropriate controls of parking and development to ensure that the network will continue to function efficiently.

Much can be done to improve the safety and capacity of existing roads by traffic management and the control of street parking. But provision for the future growth of traffic and improvement of environmental standards will entail a continuing programme of major improvement and new construction, which will need to be carefully phased with other urban development and renewal.

The magnitude of the traffic accident figures in built-up areas highlights the importance of designing urban roads for safety. Design for safety will require appropriate degrees of traffic segregation to reduce the risk of conflict and protect the more vulnerable road users. These measures will in turn promote the smoother flow of traffic and improve road capacity.

1.1.2 Traffic accidents in built-up areas

Nearly three-quarters of all road casualties occur in built-up areas, i.e. areas where speed limits of 30 or 40 mph apply. The yearly total of casualties in built-up areas is now over 280,000 and includes over 65,000 killed or seriously injured [3]

Thirteen out of fourteen pedestrian casualties occur on urban roads. A quarter of all casualties occur on such roads and a third of those killed or seriously injured are pedestrians. The groups of pedestrians most vulnerable to accidents are young children and elderly adults. The vulnerability of adults increases with age and that of children is greatest between the ages of 3 and 8. Of all road users, pedestrians incur the greatest risk of death relative to the risk of injury.

Pedestrian casualties in one-vehicle accidents were investigated during the period 1954–1957.[4] The investigations showed that on speed-restricted roads the actions of pedestrians prior to fatal or serious accidents were as follows:

	%
Crossing road masked by stationary vehicle	19
Crossing road masked by moving vehicle	4
Crossing road not masked by vehicle	46
Walking, standing or playing in road	9
Stepping, walking or running off footway or verge	16
On footway or refuge	4
Unknown	2
	100

Cyclists, moped riders and the riders and passengers of motor scooters and motor cycles are involved in about 40% of all casualties in built-up areas and make up 30% of those killed or seriously injured.

Casualty rates per million miles driven in built-up and non-built-up areas are compared in Table 1–1.[5] Although total casualty rates are higher in built-up areas it will be noted that fatality rates are generally lower, probably due to lower speeds. The table clearly shows the greater risks sustained by pedal cyclists and all types of motor cyclists as compared with other drivers. For the same distance travelled the risk of *death* for a motor cyclist is greater than that of *serious injury* for a car driver.

The peak times for casualties are:

(i) 5 pm to 6 pm on weekdays; Midday to 1 pm on Saturdays — these periods coincide with daily traffic peaks;

(ii) 10 pm to midnight on Saturdays; 10 pm to 11 pm on Sundays — these periods do not coincide with daily traffic peaks.

Table 1–1 Driver casualty rates, 1960

Class of road user	Casualties per million miles driven					
	Built-up areas			Non-built-up areas		
	Fatal	Fatal and serious	Total including slight	Fatal	Fatal and serious	Total including slight
Motor cyclists*	0.24	4.9	17.5	0.33	4 0	8.7
Scooter riders	0.14	3.6	17.9	0.20	3.0	8.3
Moped riders	0.14	2.4	9.4	0.11	1.6	3 9
Pedal cyclists	0.081	1.5	8.0	0.111	1.1	3.0
Car drivers	0.009	0.18	0.97	0.024	0.30	0.91
Other drivers	0.006	0.11	0.65	0.012	0.16	0.55

*Includes motor cycle combination riders

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Car drivers	0.009	0.18	0.97	0.024	0.30	0.91
Other drivers	0.006	0.11	0.65	0.012	0.16	0.55

*Includes motor cycle combination riders

1.1.3 Traffic segregation

Traffic segregation should be the keynote of modern road design and should be arranged to reduce the risk of conflict between one vehicle and another and between motor vehicles and slower-moving and more vulnerable road users such as pedestrians and pedal cyclists. Some examples of the application of segregation to the urban road system are outlined in Table 1–2.

The principles of segregation should be applied as far as practicable or necessary to all traffic schemes and road improvements and in the planning of new towns and the redevelopment of existing ones. The means of segregation and the rate at which it can be introduced will depend upon a variety of circumstances such as the impetus of redevelopment and the availability of funds.

Table 1–2 Some methods of traffic segregation

Type of segregation	Method	Purpose
Segregation in relation to destination	By construction of by-passes	To separate through traffic from traffic requiring to enter the town and traffic circulating within it
	By provision of separate primary and distributory traffic networks	To separate longer-distance urban traffic from local traffic
Segregation of types of traffic	By construction of urban motorways	To provide fast, high-capacity routes solely for motor traffic and eliminate accidents involving pedestrians and pedal cyclists
	By cycle tracks and cycle ways	To separate pedal cyclists from faster motor vehicles and from pedestrians
	By pedestrian ways and elevated footways	To obviate conflicts with faster traffic and give easy, direct access to various parts of the town
	By construction of back streets	To give separate access for goods and service vehicles, with facilities for loading and off-loading
	By reserving some roads or traffic lanes for buses	To ensure rapid and direct public transport and reduce interference from other traffic
Segregation of traffic by grade separation	By construction of flyovers, underpasses and grade-separated junctions	To avoid conflicts between through and crossing or turning traffic streams
	By building special subways and bridges for pedestrians or cyclists	To eliminate conflicts with motor traffic
Segregation in relation to direction	By dual or divided carriageways and one-way streets	To reduce or eliminate the risk of conflict between opposing traffic streams
	By channelising islands at junctions	To separate traffic streams and points of possible conflict, thereby simplifying the driver's task
Segregation of moving vehicles from parked vehicles	By provision of off-street parking and prohibition of street parking	To increase street capacity and eliminate risks due to screening of pedestrians from view by stationary vehicles
Segregation by other controls	By traffic signals	Use of time segregation to eliminate or reduce traffic conflicts at junctions
	By banning right turns, closing side streets and limiting access points	To reduce the risk of conflict between through and turning or crossing traffic

System of linked roof-top car parks at Coventry

Motorway M 4, London urban section on viaduct above Great West Road

1.2 Vehicles and road design

1.2.1 Vehicle dimensions and turning circles

The maximum permitted dimensions and weights of road vehicles are specified in Regulations made by the Minister of Transport.[6] Some provisions influencing road design are given below:

Maximum width of motor vehicles (including buses, but not locomotives and vehicles for abnormal loads)	8 ft. 2½ in. (2.5 metres)
Rigid vehicles:	
Maximum length (including buses)	36 ft. 1 in. (11 metres)
Gross weight:	
vehicles with 2 axles	16 tons (provided outer axles are at least 12 ft. apart)
vehicles with 3 axles	22 tons (provided outer axles are at least 18 ft. apart)
vehicles with 4 or more axles	28 tons (provided outer axles are at least 26 ft. apart)
Articulated vehicles:	
Maximum length	42 ft. 7¾ in. (13 metres)
Gross weight:	
vehicles with 3 axles	22 tons (provided outer axles are at least 18 ft. apart)
vehicles with 4 axles	32 tons (provided outer axles are at least 38 ft. apart)
vehicles with 5 or more axles	32 tons (provided outer axles are at least 32 ft. apart)
Road trains with one trailer:	
Maximum length	59 ft. 0¾ in. (18 metres)
Gross weight	32 tons

Turning circles of public service vehicles must have swept diameters no greater than 65 ft. for vehicles not exceeding 27 ft. in length and no greater than 71 ft. for longer vehicles. No such restrictions govern the turning circles of commercial vehicles; these range widely from 30 to over 80 ft. diameter, but lie mainly between 40 and 70 ft. diameter.

Loads should not normally be wider than 9 ft. 6 in., nor should they overhang the sides of a vehicle by more than 12 in.

Roads and junctions with dimensions adequate for commercial vehicles will also be suitable for private cars. Where commercial vehicles are few in number, such as on roads in residential areas, carriageway widths and junction radii may be reduced accordingly. Car dimensions normally lie within the ranges given below:

Width ....4 ft. 7½ in.–6 ft. 2 in.
Length........................10 ft.–18 ft.
Turning circles ....25 ft.–45 ft. diameter

In designing junctions with sharp curves it should be remembered that a vehicle cannot be turned from a straight path directly over to full lock and that allowance must be made for the back wheels (especially of long articulated vehicles) cutting the corner.

Typical swept paths for large commercial vehicles, both rigid and articulated, and for large cars are shown in Fig. 1–1.

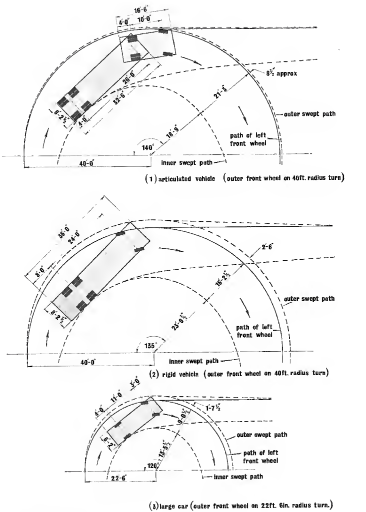


Fig. 1-1 Typical vehicular swept paths

1.2.2 Passenger car units

Vehicles of different types require different amounts of road space because of variations in size and performance. In order to allow for this in capacity measurements for roads and junctions, traffic volumes are expressed in passenger car units (pcu's). The basic unit is the car (taxis, light vans and three-wheeler vehicles also count as one unit). As different types of vehicles affect the capacity of rural roads, urban roads, roundabouts and traffic signals in varying degrees, the weighting for each class of vehicle has to be varied to suit the purpose for which it is to be used. For example, a heavy goods vehicle on a rural road is rated as equivalent to 3 cars, but on an urban road to only 2, and at traffic signals to 1.75. The appropriate values for different types of vehicles under varying conditions are given in Table 1–3.

Table 1–3 Passenger car units

Class of vehicle	Equivalent value in passenger car units (pcu's)			
	Urban standards	Rural standards	Round-about design	Traffic signal design
Private car, taxi, motor cycle combination, light goods vehicle (up to 30 cwt. unladen)	1.00	1.00	1.00	1.00
Motor cycle (solo), motor scooter, moped	0.75	1.00	0.75	0.33
Medium or heavy goods vehicle (over 30 cwt. unladen), horse-drawn vehicle	2.00	3.00	2.80	1.75
Bus, coach, trolley bus, tram	3.00	3.00	2.80	2.25
Pedal cycle ...	0.33	0.50	0.50	0.20

1.2.3 Carriageway capacity

The speed of traffic in towns will be lower than that on rural roads and there will be less overtaking; drivers are prepared for these conditions and higher traffic densities can therefore be allowed. The design of main traffic routes in built-up areas should be based on peak-hour demands and not, as in rural areas, on the average daily traffic during August. Due allowance should be made, especially in intersection design, for tidal flows during the morning and evening peaks and for any other peaks during the day—as, for example, at lunch time.

Approximate practical capacities of urban roads between junctions are given in Tables 1–4 and 1–5, which cover a wide range of carriageway widths typical of both new and existing roads. On two-way carriageways capacity is relatively independent of distribution by direction and designs can be based on two-way flows; on the other hand, on dual or divided carriageways capacity is dependent on distribution by direction and designs must therefore be based on peak-hour flows in the busier direction of travel. Recommended carriageway widths for various types of road and some typical cross-sections are given in Chapter 4.

To secure good environmental conditions, roads within environmental areas not acting as *local distributors* should desirably not be loaded to their practical capacity. All roads in environmental areas should be so designed with regard to route and junctions that they are unattractive to traffic as through routes or short cuts.

Table 1–4 Practical capacities of two-way urban roads

Effective width of carriageway in feet (excluding refuges or central reserve)	2-lane			3-lane		4-lane			6-lane			Remarks
	20′	22′	24′	30′	33′	40′	44′	48′	60′	66′	72′	
Description	Capacity in pcu's per hour for BOTH directions of flow					Capacity in pcu's per hour for ONE direction of flow						(for definitions of road types see Section 2.1)
Urban motorway with grade separation and no frontage access								3,000			4,500	Applicable to the highest category of *distributor*
All-purpose road with no frontage access, no standing vehicles permitted and negligible cross-traffic	1,200	1,350	1,500	2,000	2,200	2,000	2,200	2,400	3,000	3,300	3,600	Appropriate for all-purpose *distributors*
All-purpose street with high-capacity junctions and 'No Waiting' restrictions	800	1,000	1,200	1,600	1,800	1,200	1,350	1,500	2,000 2,200	2,250 2,450 for dual carriageways	2,500 2,700	Applicable to those *distributors* and *access roads* where access to development is frequent but capacity is not unduly restricted by junctions
All-purpose street with capacity restricted by waiting vehicles and junctions	300 to 500	450 to 600	600 to 750	900 to 1,100	1,100 to 1,300	800 to 900	900 to 1,000	1,000 to 1,200	1,300 to 1,700	1,500 to 2,000	1,600 to 2,200	Typical of existing roads where waiting vehicles and junctions with heavy cross traffic severely limit capacity

Table 1–5 Practical capacities of one-way urban roads

Effective width of carriageway in feet (excluding refuges)	20′	22′	24′	30′	33′	36′	40′	44′	48′	Remarks
Description	Capacity in pcu's per hour									(for definitions of road types see Section 2.1)
Urban motorway with grade separation and no frontage access			3,000			4,500			6,000	Applicable to the highest category of *distributor*
All-purpose road with no frontage access, no standing vehicles and negligible cross-traffic	2,000	2,200	2,400	3,000	3,300	3,600	4,000	4,400	4,800	Appropriate for all-purpose *distributors*
All-purpose street with high-capacity junctions and 'No Waiting' restrictions	1,300	1,450	1,600	2,150	2,400	2,650	3,000	3,350	3,700	Applicable to those *distributors* and *access roads* when access to development is frequent but capacity is not unduly restricted by junctions
All-purpose street with capacity restricted by waiting vehicles and junctions	800	950	1,100	1,650	1,900	2,150	2,500	2,800	3,200	Typical of existing roads where waiting vehicles and junctions with heavy cross traffic severely limit capacity

1.3 Existing and future traffic

1.3.1 Traffic censuses and surveys

For overall planning purposes, comprehensive land use/transport studies are likely to be required. They will provide information for planning the future transport requirements of the town, including the future road network, and for ensuring the adequacy of individual projects, whether large or small. The precise form and extent of any study will depend on the nature of the problems under consideration, the availability of existing information and the size of the town. Traffic censuses and surveys, either as part of the comprehensive study or taken separately, will provide information about specific road problems.

The main types of traffic study are:

Traffic censuses	To determine traffic volumes and composition on roads and at junctions.
Traffic surveys	To ascertain by home and/or roadside interviews the number, timing, and origin and destination of journeys.
Pedestrian censuses	To assess the adequacy of footways or the need for pedestrian crossings, subways, or pedestrian-operated traffic signals.
Pedestrian surveys	To locate and measure the main pedestrian flows, e.g. for a system of pedestrian ways.
Public transport surveys	To assess the use and adequacy of public transport services.
Parking surveys	To ascertain the availability and usage of on-street and off-street parking space and the duration of parking.
Speed and delay studies	To measure the adequacy of the road system; for the assignment of traffic to routes; for the preparation of economic assessments.
Accident studies	For the identification of points of special danger and of the causes of accidents.

Censuses and surveys should be kept up-to-date so that trends can be determined, changes in travel habits detected and any necessary amendments made to the overall plan. Information on the conduct of censuses and surveys and the analysis of the results may be obtained from *Urban Traffic Engineering Techniques*.[7]

1.3.2 Future traffic

Up to the present, forecasts of future traffic in towns have largely been based on the extrapolation of present trends, with allowances for growth ranging from 60% for very large towns to 150% for others. As survey and forecasting techniques are improved it will be possible to relate forecasts more closely to the needs of individual towns and to design road networks in relation to the varying requirements of different parts of the town. Each town will be able, by the traffic policies it pursues, to influence directly the volume of traffic circulating within it.

Some points to be considered initially and as roadworks and development proceed are:

(i) When a road is widened or a new road constructed in a built-up area further improvement may well be precluded for many years by erection of buildings alongside the road. It is important therefore that road projects should be adequate and compatible with longer-term development proposals for the town as a whole.

(ii) Where there are land acquisition or other difficulties, interim improvements of lesser capacity than that ultimately required may be economically justifiable. But as new development proceeds it may be necessary to fix building lines or limit the life of development alongside the road to allow for its eventual widening and the construction of higher capacity junctions.

(iii) To avoid overloading of the network, continuing control of parking will be necessary, together with positive action to avoid over-concentration of traffic-generating development, particularly in central areas.

(iv) As indicated in *Urban Traffic Engineering Techniques*,[7] cost-benefit analysis may be used to compare alternative schemes or to assess priorities, having regard to time lost through traffic delays and the cost to the community of accidents. But present methods are not sufficiently refined always to give full financial justification and do not make any allowance for possible effects on environment. As research is in progress on the development of techniques, the most up-to-date information should be sought before commencing a cost-benefit analysis.

2 The urban road system

2.1 Road types

In this manual reference is made to four main types of urban road:

(i) *Primary distributors* — These roads form the primary network for the town as a whole. All longer-distance traffic movements to, from and within the town should be canalised on to the *primary distributors*.

(ii) *District distributors* — These roads distribute traffic within the residential, industrial and principal business districts of the town. They form the link between the primary network and the roads within environmental areas (i.e. areas free from extraneous traffic in which considerations of environment predominate over the use of vehicles).

(iii) *Local distributors* — These roads distribute traffic within environmental areas. They form the link between *district distributors* and *access roads*.

(iv) *Access roads* — These roads give direct access to buildings and land within environmental areas.

For clarity these road types are referred to in italics throughout the manual. The relationship between them is illustrated in Fig. 2–1 and their role is discussed in Sections 2.3 to 2.5.

Fig. 2–1 Urban road types

2.2 Diversion of through traffic from urban streets

The existing road pattern in Great Britain still consists largely of a network of roads linking towns and passing through town centres ill-suited to handle the growing volume of through and local traffic. If the volume of through traffic is large enough, the best way of diverting it from a town on a major through route may be by providing an outer by-pass or (if a number of roads converge on the town) by constructing a partial or complete outer ring road. If, on the other hand, the amount of through traffic does not warrant an outer by-pass or ring road, or if its use would involve such a lengthy detour that drivers would take a short cut through the town, a better alternative may be to provide an internal relief road for both the through traffic and the longer-distance internal traffic. The relief road would then form part of the town's primary road network. When both an outer by-pass and an internal relief road are planned, quicker relief of congestion and greater economic benefit will sometimes result from the prior construction of the latter.

Such measures will not obviate the need to improve the efficiency of the existing road system by traffic management together with a programme of improvements to eliminate the worst trouble-spots.

To avoid overloading the primary network of very large towns it may be necessary to allocate separate routes for both through traffic and the longer-distance movements within the town. These

routes (called regional distributors in the Buchanan Report[9]) would serve a wider area than the usual primary network. They would have a limited number of connections to the primary network and would normally be designed to the same standard.

Regional distributors will also be required to serve conurbations, where they should be linked by *primary distributors* to the main centres of development. Wherever possible, existing motorways or other major routes passing through conurbations should be utilized as regional distributors.

2.3 *Primary distributors*

An efficient road system will be needed to enable traffic to enter or leave the town rapidly and safely, or to circulate freely within it; the system should also accommodate any through traffic not diverted to outer by-passes or ring roads. This can be achieved by means of a network of *primary distributors* linking the business, industrial and residential districts, which should have separate *distributor* and *access road* systems to enable traffic to reach houses, factories, shops, vehicle parks, etc.

For maximum capacity and safety, *primary distributors* should ideally be designed with full restriction of frontage access. In large towns and cities where traffic flows are heavy, grade separation and motorway status will need to be considered. Where such standards are not economically justifiable or cannot be obtained it will be necessary to designate existing or proposed all-purpose roads as *primary distributors*, steps being taken to restrict frontage access, street parking and the number of turning and crossing movements to the maximum extent which is practicable.

The shape of the primary network will be determined by the traffic requirements of the town, and these in turn will be influenced by topography and the pattern of development. Some typical network layouts are illustrated in Fig 2–2. Probably the most widely used is the radial-ring pattern in which a number of radial roads are linked to one or more ring roads. But this layout will not always be the most suitable, and it is important that a whole range of designs should be considered and tested at the planning stage.

The design standards recommended for *primary distributors* may be unnecessarily high for smaller towns, and those recommended for *district distributors* should normally be adequate.

2.4 *District distributors*

In the same way that *primary distributors* serve the town as a whole, *district distributors* will serve specific localities comprised of groups of environmental areas, such as the town centre or large residential districts. *District distributors* will feed traffic from the primary network to these districts but will not traverse environmental areas. Although these roads may link adjoining districts they are not intended for the longer cross-town journeys, for which the primary network should provide a more attractive alternative. It is particularly important that drivers should not be able to use any *district distributors* in the town centre as through routes.

The prime function of *district distributors* will be to facilitate the safe and unhindered movement of traffic within the districts they serve. This function should be preserved by appropriate restrictions on frontage access and street parking. Although prohibition of access and parking may initially be impracticable on existing roads, an increasing degree of restriction should be applied as redevelopment takes place and alternative facilities become available. The immediate application of such restrictions to new roads should usually present no difficulty. Parking

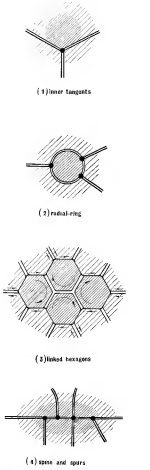


Fig. 2–2 Examples of network layouts

Distributor roads and interchanges at Cumbernauld (*reproduced by courtesy of the Cumbernauld Development Corporation*)

provision and the nature and extent of development within districts should be related to the capacity of their road systems.

As indicated in Section 2.3 the design standards recommended for *district distributors* should usually be adequate for the primary network in smaller towns. In some cases a separate hierarchy of *district distributors* may be unnecessary, e.g., where the primary network surrounds a single environmental area such as the centre of a small town.

2.5 *Local distributors* and *Access roads*

Local distributors and *access roads* will serve and be located within environmental areas, which will be bounded but not crossed by *primary* or *district distributors*. Traffic from the major distributors will penetrate into environmental areas on the *local distributors* and will gain access to houses, shops, offices, factories and other development via *access roads*. As in the case of other distributors, the function of *local distributors* should be preserved by appropriate restrictions on frontage access and street parking.

In new towns and areas of extensive redevelopment, environmental areas will often be planned so that pedestrian and vehicular access to premises are separated, e.g. by means of:

Radburn-type layouts for housing estates;
pedestrian precincts;
pedestrian ways separated horizontally or vertically from streets carrying vehicular traffic;
back streets giving goods and service vehicle access to shops, offices, factories, etc.

However, the streets in many environmental areas, especially existing streets, will have to serve both vehicular and pedestrian traffic and can do so satisfactorily provided they are not unreasonably congested by parked and moving vehicles. Where necessary, environmental standards and safety should be improved by prohibiting or restricting street parking (with appropriate provision for off-street parking) and providing a system of back streets for servicing premises. It may be practicable to close some shopping streets to vehicular traffic for all or part of the day.

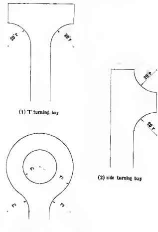
Many *access roads* will be culs-de-sac. It is important that there should be sufficient space for vehicles to turn around at the end of such culs-de-sac. Suggested designs for turning circles and bays in residential streets are given in Figure 2–3.

2.6 Stages of improvement

It will often be convenient to implement the planned improvement of the urban road system in the following sequence:

(i) Prohibit or restrict waiting on *primary* and *district distributors*. During peak traffic periods prohibit the loading and unloading of commercial vehicles and limit stopping to pick up or set down passengers as on urban clearways.
(ii) Take urgent action to provide off-street parking accommodation, consistent with a policy relating the availability of parking space to the capacity of the network. Site garages and car parks near the main centres of development, with easy access to distributor roads.
(iii) Construct secondary means of access to enable goods and service vehicles to load or unload at the rear of shops and other premises. Where it is not immediately possible to provide these to full vehicular width, the interim construction of rear alleyways wide enough for the operation of trolleys or fork-lift trucks should be considered. These alleyways should terminate at suitably sited loading bays on minor streets.
(iv) Prohibit or restrict street parking on *local distributors* and *access roads* in conjunction with the planned provision of car park spaces and the availability of back streets for servicing shops, etc.
(v) Construct or improve *primary* and *district distributors* to the required standards. This work should be carried out concurrently with stages (i) to (iv) and programmed so that the most-needed sections are completed first.
(vi) As the primary network is developed, introduce traffic control to canalise cross-town journeys on to *primary distributors* instead of *district* and *local distributors*.

Fig. 2–3 Vehicle turning points for residential culs-de-sac



(1) 'T' turning bay

(2) side turning bay

radius	cars only	all vehicles
r_1	15	30
r_2	30	50
r_3	20	35

(3) turning circle

Shopping precinct, Coventry Town Centre

Entrance to underground garage beneath Hyde Park, London

Multi-storey car park adjoining Bull Ring Centre, Birmingham

3 Factors affecting alignment

3.1 The road and its surroundings

The urban road pattern will be influenced by the topography of the town, the position of the main business, shopping, industrial and residential districts, and the disposition of the major roads outside the town. The route and detailed alignment, both horizontal and vertical, of the individual town road will be affected not only by local topography and development but by the need to conform to the standards of curvature, gradient and visibility appropriate to its purpose.

Road design is an exercise in three-dimensional planning whose success will be measured not only by the efficiency of the road but by its appearance and impact upon the neighbourhood. The road and its associated structures should have a pleasing appearance from its surroundings as well as from the viewpoint of the road user. It should not adversely affect its environment by allowing the noise and fumes of traffic to become obtrusive. It should not sever communities or unduly restrict cross-movement. Meeting these requirements will present many problems in planning new towns or extensive areas of redevelopment, but will require even more ingenuity in areas of existing development. Some of the factors to be considered at an early stage in the planning of new roads or the improvement of existing ones are considered below.

3.1.1 Location and alignment

In towns there will usually be less scope for fitting the road to the landscape than in the countryside, but every effort should be made to do this so far as circumstances allow. Roads on gentle curves fitting the contours of the ground afford opportunities for attractive design and have the advantage of presenting the road-user with a continuously changing forward view. Provided it is not too long, a straight alignment can often be pleasing; it expresses directness of purpose and lends itself to the closing of the vista by a suitable terminal building. Opportunities should be taken of affording views of the surroundings and especially of buildings of architectural or historic interest, provided this can be done without detriment to amenity.

Where possible, horizontal and vertical curves should be phased to coincide or should be contiguous, with common tangent points. It will enhance the appearance of the road if curves are reasonably long and adjacent curves are similar in length. Small changes of direction are undesirable as they tend to give a disjointed appearance to the view of the road ahead.

Adjoining horizontal or vertical curves of the same or opposite sense which are visible from one another should not be connected by a short straight. It is better to introduce a flat curve between curves of the same sense or to extend curves of the opposite sense to a common point.

Sharp horizontal curves starting at a summit may be dangerous as drivers may not be able to see them in time. Sharply undulating profiles are undesirable as drivers may be tempted to overtake without realising that oncoming vehicles may be hidden from view in the dips.

3.1.2 Elevated and sunken roads

Where the need for grade separation on urban motorways and other important routes entails their construction as elevated or sunken roads, great care will obviously be needed in their location and planning to avoid destruction of amenity and disruption of local communications.

Sunken roads in tunnel can be planned so as not to interfere with surface roads or development, but the high cost of tunnels may inhibit their construction unless development is allowed above them. Sunken roads in cutting do not form a visual barrier but may restrict cross-traffic at surface level; they should usually be depressed about 20 ft. below the existing street system to ensure adequate headroom at bridges without having to regrade the streets on the bridge approaches. Unless the road is flanked by retaining walls, extra width will be required to accommodate side slopes, though these will help to give the road an open appearance and will afford opportunities for planting and landscaping. Building the road in cutting and planting the slopes will help to muffle traffic noises. The diversion of public utility services crossing the road and the drainage of surface and ground water in the cutting may present difficulties. Sunken roads can be linked to the existing street system more easily than elevated roads as the slip road gradients assist deceleration when leaving the sunken road and acceleration when joining it.

Elevated roads may be on embankment or viaduct and can be designed to cause little or no interference to cross-streets and underground services. They are easier to drain than sunken roads. Viaducts require less space than roads on embankment and will be more suitable in constricted areas; they have the advantage that supporting piers can be arranged and spaced to fit in with existing features or property. The space underneath elevated roads can sometimes be used for buildings or parking. Although elevated roads will be conspicuous because of their height and size, there is no reason why they should be detrimental to amenity provided they are well designed and properly sited. Their alignment may largely be governed by the location of interchanges, but where possible they should be sited well away from existing buildings, particularly in residential areas. To minimise interference to existing property it may sometimes be possible to route elevated roads above railways or through areas due for redevelopment.

3.2 Design speeds

The design speed of a highway is that chosen for the correlation of such features as sight distances, curvature and superelevation upon which the safe operation of vehicles depends. It is the maximum speed maintainable throughout the journey compatible with safety and comfort when weather and traffic conditions are favourable and the geometric features of the highway are the controlling factors.

Suggested design speeds for urban roads are as follows:

Primary distributor: urban motorway	50 mph
Primary distributor: all-purpose	40 mph
District distributor, local distributor, important *access road*	30 mph

These recommendations are intended only as a guide; it may sometimes be practicable to raise, or necessary to lower, the

design speed for certain types of road or for parts of a road, though 30 mph should be regarded as the minimum value for all distributors. For example, physical restrictions on the alignment of an urban motorway may make it impracticable to achieve a design speed of 50 mph, and a standard of 40 mph may have to be accepted instead.

3.3 Sight distances

Sight distances, both vertical and horizontal, should be measured between points 3 ft. 6 in. above the carriageway along the centre lines of both the nearside and offside lanes of the carriageway. On dual-carriageway roads sight distances should be checked on both carriageways.

On single-carriageway roads sufficient visibility for safe overtaking should be provided on as much of the road as possible. It will often be impracticable to achieve this standard, especially in hilly districts or where there are buildings close to the road on the inside of a curve, but in no case should visibility be less than the minimum stopping distance given in Table 3-1. Particular care should be taken to ensure that on horizontal curves visibility is not restricted by shrubs, bridge piers or other obstructions at the side of the road or on the central reserve.

Table 3-1 Minimum sight distances

Design speed mph	Sight distances: Minimum overtaking distance (single carriageway) ft	Sight distances: Minimum stopping distance (single and dual carriageways) ft
50	1,200	425
40	950	300
30	700	190
20	480	110

Car park under Hammersmith Flyover

3.4 Gradients

A gradient of 1 in 25 should ordinarily be regarded as the maximum on the through carriageways of urban motorways and other *primary distributors*, but in hilly districts and other difficult locations gradients of up to 1 in 20 may have to be accepted on urban motorways and even steeper gradients on all-purpose roads. Steep gradients should be kept as short as possible.

It is impracticable to specify a maximum gradient for other urban roads, as these are more likely to be affected by the restrictions of topography and development than *primary distributors*. Although the same standards as for *primary distributors* should be used wherever possible, particularly for *district distributors*, the adoption of steeper gradients will sometimes be unavoidable despite their adverse influence on road capacity and safety. Junctions should preferably be located away from steep gradients, especially where the road is on a curve.

On steep sections of heavily trafficked roads the installation of road heating may be warranted to prevent the formation of ice on the road surface.

To avoid congestion on busy distributor roads with long, steep gradients the provision of a special climbing lane for the slower-moving commercial vehicles may be warranted. It is suggested that the economic case for providing a climbing lane should be examined where grade lengths exceed the values given in Table 3-2, which is based on American recommendations.[8] On a single three-lane carriageway a climbing lane may be obtained by providing an offset double white line, with permissive marking for downhill overtaking where visibility is adequate.

Table 3–2 Critical grade lengths

Gradient %	Critical grade length ft.
3	1,600
4	1,100
5	800
6	650

To facilitate the drainage of surface water, channel gradients steeper than 1 in 250 are desirable If possible the general road gradient should be steeper than 1 in 250, but where flatter gradients have to be accepted it may be necessary to steepen the channel between gullies to obtain the required minimum fall.

3.5 Vertical curves

Vertical curves should be provided at all changes of gradient. In urban areas the restrictions imposed by topography and development may not permit correlation of horizontal and vertical curves to the same extent as in rural areas, but where possible this should be done.

To ensure reasonable standards of comfort and appearance and to secure appropriate visibility at summits, vertical curves should not be shorter than:

(i) indicated by the formula $L = KA$, where L is the curve length in feet, A is the algebraic difference in gradients (expressed as a percentage) and K has a value selected from Table 3–3, or
(ii) shown in the fourth column of the table if longer than (i).

Summit curves designed using the K values given in the second column of the table will have sight distances just adequate for overtaking on two-way roads with a single carriageway The K values shown in the third column will ensure acceptable stopping sight distances at summits and a reasonable ride at both summits and valleys; these minimum standards will apply to dual-carriageway roads, one-way roads and those two-way single-carriageway roads where physical conditions preclude the achievement of better visibility.

Where K values of over 125 are used the channel gradients at summits and valleys will be flatter than 1 in 250 for more than 100 ft., and surface water drainage may require special attention.

Table 3–3 Minimum vertical curve lengths

Design speed mph	Minimum K value for overtaking	Minimum K value for stopping and comfort	Minimum vertical curve length ft.
50	—*	65	150
40	—*	35	120
30	175	20	90
20	85	10	60

*Values not quoted as dual-carriageway layouts will normally be appropriate for these design speeds

3.6 Horizontal curves and superelevation

It is desirable that all-purpose roads in urban areas should not be superelevated too steeply, and superelevation should preferably not exceed 1 in 24 on roads with single-level junctions and little or no restriction of frontage access In no case should superelevation be steeper than 1 in $14\frac{1}{2}$ or flatter than the standard carriageway crossfall. Adverse camber should be eliminated or superelevation introduced where necessary.

As indicated in Ministry of Transport Memorandum No. 780[9] superelevation should normally be 1 in $\frac{37r}{V^2}$, where V is the design speed in mph and r the curve radius in feet. Values for design speeds of 30, 40 and 50 mph are shown in Fig. 3–1. The minimum radius for any given design speed and superelevation is governed by the formula $\frac{V^2}{15r} = s + f$, where s is the superelevation in feet per foot and f the side-friction factor. Table 3–4 compares normal and minimum radii for certain design speeds and rates of superelevation; the minimum values assume side-friction factors of 0.18 up to and including 30 mph and 0.15 at higher speeds.

Table 3–4 Normal and minimum radii for 1 in 24 and 1 in $14\frac{1}{2}$ superelevation

Design speed mph	Normal radius (ft.) for superelevation of: 1 in 24	1 in $14\frac{1}{2}$	Minimum radius (ft.) for superelevation of: 1 in 24	1 in $14\frac{1}{2}$
50	1,620	980	870	760
40	1,040	630	560	490
30	590	360	270	240
20	260	160	120	110

On curves with radii below those given in the second column of Table 3–5 it is recommended that adverse crossfall or camber should be eliminated to give a uniform crossfall towards the inside of the curve. On curves with greater radii the elimination of adverse crossfall, though not essential, will sometimes be desirable on the grounds of appearance. Transition curves are desirable at the ends of curves with radii below those shown in the last column of the table; it will often be useful to provide transitions for curves of greater radius to improve their appearance and facilitate the introduction of superelevation or the elimination of adverse camber.

Table 3–5 Radii for elimination of adverse camber or provision of transition curves

Design speed mph	Eliminate adverse crossfall if radius is less than: ft.	Provide transition curves if radius is less than: ft.
50	6,000	4,000
40	4,000	2,000
30	2,000	1,000
20	1,000	500

Superelevation should not be introduced or adverse crossfall removed so gradually as to create large almost-flat areas of carriageway or so sharply as to cause discomfort or give the edges of the carriageway a kinked appearance. A satisfactory appearance can usually be achieved by ensuring that the carriageway edge profile does not vary in grade more than about 1% from that of the line about which the carriageway is pivoted and by ample rounding-off of all changes in edge profile. Where transition curves are provided, superelevation or removal of adverse crossfall should be effected along their length In other cases about two-thirds of the cant should be introduced on the approach straight and the remainder at the beginning of the curve.

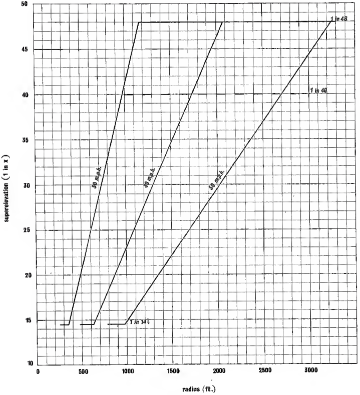


Fig. 3–1 Superelevation values for various radii

4 The road in cross-section

The width and layout of a road will depend largely upon the type, volume and speed of the traffic it will carry. The design of the various components of the road for the accommodation and safety of vehicular and pedestrian traffic is considered below.

4.1 Carriageways

4.1.1 Traffic lanes

Lane widths should be chosen with particular regard to the type, volume and speed of traffic using the road. Recommended lane widths for various types of road are given in Table 4–1.

Table 4–1 Recommended lane widths

Road type	Recommended lane widths: Single two-lane carriageway	Dual or divided carriageway with at least four lanes
Primary distributor	—	12 ft.
District distributor	12 ft.	12 ft. normally 11 ft. if the proportion of heavy commercial traffic is fairly low
Local distributor	12 ft. in industrial districts 11 ft. in principal business districts 10 ft. in residential districts	—
Access road	Principal means of access: 12 ft. in industrial districts 11 ft. in principal business districts 9 ft. normally in residential districts	—
	Secondary means of access: 10 ft. in industrial and principal business districts On back roads in residential districts a *two-lane* width of 13 ft. will suffice if use is limited to cars	—

A nearside lane width of 14 ft. may be desirable on roads carrying large numbers of cyclists.

At single-level junctions where additional lanes are required for turning traffic but where space is restricted it may be necessary to reduce the normal lane width to 9 ft. or exceptionally even to 8 ft. 6 in.

4.1.2 Lane widening on curves

An appropriate amount of lane widening on sharp curves is desirable on all roads. On roads with 12 ft. traffic lanes the carriageways on curves of less than 500 ft. radius should be widened by 1 ft. per lane. For lane widths of less than 12 ft. the added width should be 1 ft. per lane on curves of less than 1,500 ft. radius, increasing to 1 ft. 6 in. per lane on curves of less than 1,000 ft. radius and to 2 ft. per lane on curves of less than 500 ft. radius. The recommendations apply to curves of 300 ft. radius and over, recommended lane widths for sharper curves such as on connecting carriageways in junctions are given in Table 10–2.

No lane widening is required on three-lane carriageways marked as two lanes on curves.

4.1.3 Carriageway widths

Roads should be planned with sufficient width for the estimated future traffic. This should be done even where land acquisition and provision of the full capacity required is to be carried out in stages. Where necessary, provision should be made for additional lanes on the approaches to junctions to accommodate right- or left-turning traffic.

Except possibly in tidal-flow systems, carriageways for two-way traffic should normally have an even number of lanes. Three-lane carriageways with a central overtaking lane are not appropriate for urban traffic conditions and, if future traffic volumes exceed two-lane capacity, at least four lanes should be provided where practicable. Where the opposing traffic streams are separated by a chain of refuges or a continuous central reserve the overall width should be increased to accommodate that of the refuges or reserve.

If suitable arrangements can be made to indicate the direction of travel in each lane the introduction of a tidal flow system may allow some economy in the number of lanes required. Except possibly on short lengths, two-way tidal flow is unlikely to be satisfactory on three- or four-lane carriageways (i.e. where only one lane would be available for the lighter flow and might easily be blocked by a waiting or broken-down vehicle) but may be suitable for wider roads where at least two lanes are available for the lighter flow. Arrangements for tidal flow are more difficult on roads where opposing traffic streams are separated by a dividing island, but may be warranted on certain heavily trafficked routes, e.g. on radials with heavy flows inwards in the morning and outwards in the evening. In such cases provision for tidal flow may be made by construction of three carriageways instead of two, thereby allowing for reversal of flow on the centre carriageway. A tidal flow system for a three-carriageway urban motorway is shown in Fig. 4–1.

On urban motorways the opposing traffic streams should always be separated. Separation will usually be effected by means of a central reserve but can also be achieved by one-way road systems

One-way tidal flow on Albert Bridge: morning flow into Central London

One-way tidal flow on Albert Bridge: evening exodus from London

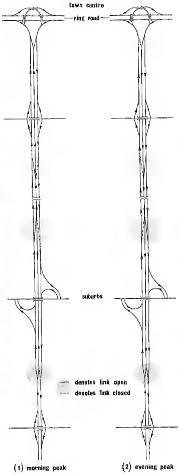


Fig. 4-1 Tidal flow on three-carriageway urban motorway

or by building one carriageway above the other. Dual-carriageway layouts or other methods of separation will also be appropriate for *primary distributors* and for *district distributors* carrying large volumes of traffic, such as those serving business and industrial areas. The number of lanes in each direction will depend upon the estimated future traffic but should not be less than two and will rarely need to be more than four.

4.1.4 Camber and crossfall

Except on curves where superelevation or elimination of adverse crossfall or camber is required, carriageways should normally have a crossfall neither steeper than 1 in 40 nor flatter than 1 in 48 from the crown or central reserve downwards towards the side of the road. Excessive camber is a source of danger to drivers and cyclists and should be eliminated. Not only does it reduce the traffic capacity of the road but it may cause loads to be displaced or lead to vehicles side-slipping in icy conditions.

At the junction of a side street with a major road the carriageway of the side street should be graded into the channels of the major road, which should retain its normal cross-section throughout the junction.

Where new or improved roads with dual carriageways have to be fitted to existing features, varying the level of the two carriageways may be helpful. Even on roads with only a single carriageway a difference in kerb levels may be useful, provided due care is taken in the treatment of the camber and crossfalls.

4.1.5 Kerbs

Kerbs should normally be light-coloured and should be clearly distinguishable from other parts of the road by day or night and in wet or dry weather.

As shown in Fig. 4-2 raised kerbs with vertical or half-batter faces about 4 in. high should be provided where footways or cycle tracks lie within about 10 ft. of the carriageway or where obstructions such as bridge piers and lighting columns are less than 5 ft. from the carriageway. 45° splayed kerbs may be installed instead where greater clearances are available or safety fences are provided.

On roads without footways or cycle tracks, or where these are on embankment above the road or separated from it by safety fencing, lip or flush kerbs or marginal strip markings may be used, provided obstructions such as bridge piers and lighting columns are at least 5 ft. clear of the carriageway and the face of any safety fence is at least 4 ft. from the carriageway. Flush kerbs or marginal strips are not suitable where positive control of drainage is required at the edge of the carriageway. The provision of a slight ripple or corrugation on the face of a flush kerb (not enough to cause danger to two-wheeled vehicles) may help to prevent overrunning by setting up an audible vibration in an encroaching vehicle but should not be regarded as an alternative to making the kerb adequately visible.

Where footways are much used by perambulators or wheelchairs, kerb heights should be reduced to about 1 in. above channel level adjoining pedestrian crossings and other suitable crossing points. The footway should be ramped down in an easy slope towards the lowered kerb.

4.1.6 Central reserves

On urban roads requiring more than two traffic lanes it will usually be desirable to separate the opposing traffic streams by a central reserve unless tidal flow operation is envisaged.

Although central reserves will often be narrow because space is restricted, the adoption of a greater width where conditions permit will enhance the appearance and safety of the road. A reserve width of at least 6 ft. is desirable, especially at points where pedestrians have to cross the road, but a minimum width of 4 ft. may have to be adopted at pinch points. Where there are bridge piers, lighting columns, etc. on the reserve the minimum width will depend upon the width of the obstructions and the clearances needed between them and the carriageways; minimum clearances are given in Table 4-2.

Reserves 6 ft. wide or less should normally be paved and bordered by raised kerbs. The type of kerb should be chosen in accordance with Sub-Section 4.1.5. The paving should be either slightly cambered or dished for ease of drainage and should preferably contrast with the carriageways in colour and texture. Where conditions are suitable for the growth of grass, reserves over 6 ft. wide may be grassed, provided there are no fences or other obstructions along the reserve which would interfere with grass-cutting operations. Special consideration should be given to the drainage of surface water from wide reserves; the adoption of a slightly dished cross-section will ensure that water does not run across the carriageways.

On curves the central reserve should normally have the same cross-section as on straights. Where, however, the method of superelevation involves the tilting of the reserve its crossfall should not be dangerously steep. Unless safety fencing is installed to protect traffic the crossfall should not usually be steeper than 1 in 6.

Obstructions on the reserve are a potential danger to traffic and their number should be kept to a minimum. Care should be taken to ensure that they do not unreasonably restrict visibility on bends or at junctions; widening of the reserve may be necessary to give the required minimum sight distances. On urban motorways and other heavily trafficked roads where speeds are high, safety fencing erected in advance of obstructions will be needed for the protection of vehicles; if the reserve is narrow the erection of continuous safety fencing may be warranted not only to screen obstructions but to prevent accidents due to vehicles crossing the reserve.

On the approaches to an intersection the central reserve may have to be widened to accommodate a lane for right-turning traffic. Care should be taken to ensure that these local widenings do not spoil the general alignment of the carriageways.

Low kerb at pedestrian crossing

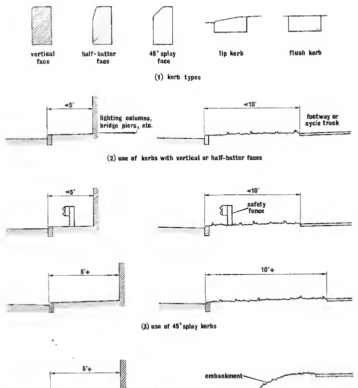

vertical face
half-batter face
45° splay face
lip kerb
flush kerb
(1) kerb types
<5'
lighting columns, bridge piers, etc.
<10'
footway or cycle track
(2) use of kerbs with vertical or half-batter faces
<5'
<10'
safety fence
5'+
10'+
(3) use of 45° splay kerbs
5'+
embankment
4'+
4'+
(4) use of flush or lip kerbs or marginal strip markings

Fig. 4–2 Kerbs

4.1.7 Central reserve crossings

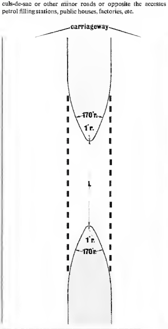
On urban motorways central reserve crossings will be needed to enable traffic to be diverted from one carriageway to the other in the event of an emergency or to enable maintenance and repairs to be carried out. A typical crossing is shown in Fig. 4–3.

Crossings should normally be provided in the following positions along urban motorways:

(i) near to all terminal junctions;
(ii) at other junctions approximately opposite the mid-point of all acceleration and deceleration lanes (where speed change lanes are arranged in pairs on either side of the motorway one crossing will suffice for each pair);
(iii) at intervals of approximately one mile between all junctions.

When not in use, crossings should be closed to traffic by means of light, easily-removable barriers.

On all-purpose roads with dual carriageways and single-level junctions it will not usually be necessary or desirable to provide crossing places other than those that may be needed at major junctions. Crossings should not normally be provided opposite culs-de-sac or other minor roads or opposite the accesses to petrol filling stations, public houses, factories, etc.



central reserve width (ft.)	4	6	8	10	15	20
crossing length L (ft.)	75	65	60	55	50	45

Fig. 4–3 Central reserve crossings

4.1.8 Divided carriageways

On roads where traffic speeds are restricted to 30 mph the separation of traffic streams by a chain of refuges instead of a continuous central reserve may have to be accepted. Refuges along divided carriageways should preferably be not more than 100 yds. apart and should be inter-visible. Where possible the normal lane width should be maintained past refuges; if the street width is limited the clearances between a refuge and the kerbs may have to be reduced slightly but should not be less than 18 ft.

To enable refuges to be seen easily they should have internally illuminated bollards at each end and an indicator lamp about 16 ft. high in between. The indicator lamp should be sufficiently well illuminated to be clearly visible at night but should not be so brightly lit as to cause distraction to drivers or become a substitute for the normal street lighting. The lamp standard should be positioned to minimise obstruction to pedestrians. It may sometimes be necessary to site a street lighting column at a refuge instead of an indicator lamp.

Refuges should normally be 6 ft. wide and never less than 4 ft. wide. They should have openings in the centre at carriageway level for the convenience of pedestrians, especially of those with perambulators. Both ends of the refuge should be tapered and not semicircular in plan, and should be formed by kerbs about 4 in. high with light-coloured vertical or near-vertical faces. White warning lines should be painted on the carriageway on the approaches to the refuge.

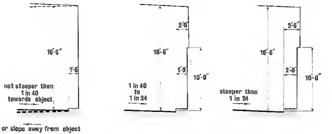
4.1.9 Clearances

Recommended minimum clearances between the edge of the carriageway and obstructions on the footway, verge or central reserve are specified in Table 4–2 and illustrated in Fig. 4–4. The clearances allow for overhanging loads and the tilting of vehicles towards the obstruction by the crossfall or super-elevation of the carriageway. To encourage the correct placement of vehicles on the carriageway, greater clearances should be provided where possible, especially on roads with design speeds above 30 mph. Where an obstruction is located on the inside of a bend a greater clearance than that specified may be required to ensure that the sight distance is not less than the minimum stopping distance.

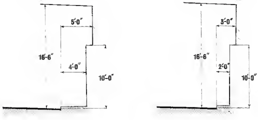
Table 4–2 Clearances from the carriageway

Design speed mph	Height of object on footway, verge or central reserve	Minimum clearance where carriageway crossfall is: away from object, or towards object but not steeper than 1 in 40	towards object but not steeper than 1 in 24	towards object and steeper than 1 in 24
30	Less than 10′ 0″	1′ 6″	1′ 9″	2′ 0″
	10′ 0″ and above	1′ 6″	2′ 0″	2′ 6″
40 or 50	Less than 10′ 0″	Minimum in all cases ... 2′ 0″ Desirable where conditions permit 4′ 0″		
	10′ 0″ and above	Minimum in all cases ... 3′ 0″ Desirable where conditions permit 5′ 0″		

Six-lane divided carriageway



(1) clearances for 30 m.p.h.



(2) clearances for 40 or 50 m.p.h.

Fig. 4-4 Minimum clearance profiles

4.1.10 Lay-bys

On existing *district* and *local distributors* there will seldom be room for the construction of lay-bys, though their provision should be considered as part of the measures to relieve congestion at those bottlenecks where it has been necessary to tolerate some waiting despite obstruction to the flow of traffic. As proposals for future development should include adequate arrangements for off-street parking and service access to premises, lay-bys should rarely be needed on new or extensively improved streets in these categories.

On all-purpose *primary distributors* (which are intended primarily for the rapid movement of large volumes of traffic) the provision of lay-bys at regular intervals will help to maintain steady flow by enabling a driver to stop clear of the carriageway if, for example, he needs to consult a map, check the loading or functioning of his vehicle or visit a nearby convenience. The presence of lay-bys at fairly frequent intervals should also help to reduce the number of breakdowns on the carriageway. It is accordingly recommended that lay-bys should be spaced at intervals of not more than one mile on each side of these roads. They should also be provided on those lengths of urban motorway without paved verges, where they should be spaced at intervals of not more than half a mile along each carriageway. They should not be sited where their use might unduly restrict visibility or interfere with the movement of traffic, as, for example, on the inside of a bend or on the approaches to a junction.

Typical layouts for lay-bys are shown in Fig. 4–5. To enable vehicles to leave or rejoin the carriageway smoothly, lay-bys should have tapered ends. They should normally be 10 ft. wide and at least 100 ft. long excluding the end tapers. Lesser widths may have to be accepted where space is restricted, but where possible lay-bys should be at least 8 ft. wide. Suitable arrangements should be made for the drainage of surface water from lay-bys; a crossfall outwards from the kerb towards the carriageway will reduce the risk of splashing.

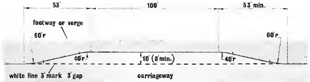
It will often be convenient to site lay-bys and bus bays together. As shown in Fig. 4–5 a combined lay-by and bus bay should be at least 150 ft. long excluding end tapers and between 9 ft. and 10 ft. 9 in. wide.

On roads linked to the national motorway network, lay-bys should be installed at convenient points near the interchanges to enable drivers to check their vehicles or consult maps before entering or after leaving the motorway.

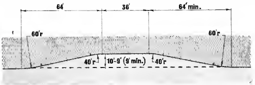
4.2 Footways

4.2.1 Footway widths and construction

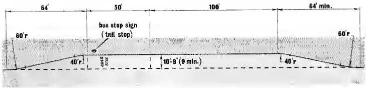
When designing new roads or improving existing ones in urban areas, it should be considered whether alternative arrangements should be made for pedestrians which would dispense with the need for footways alongside the carriageway. If, however, footways are provided they should be amply wide and comfortable to walk upon, so as to minimize any tendency for pedestrians to walk along the carriageway. They should have well-maintained surfaces with crossfalls neither so flat as to be difficult to drain nor so steep as to be dangerous to walk upon. Crossfalls within the range 1 in 40 to 1 in 30 should meet these requirements. Surfaces should not be slippery and should be carefully graded to avoid ponding. Paving slabs should be firmly bedded, with close, flush joints; bituminous surfacings should be free from loose chippings.



(1) lay-by



(2) standard bus bay



(3) combined lay-by and bus bay

Notes:

1. The run-out length should be increased where difficulties of visibility or exit make this desirable.
2. At bus bays the bus stop sign should be erected at the point where passengers enter and alight.
3. Where provision has to be made to accommodate more than one vehicle in a bus bay at the same time, the length of the widest section should be increased to allow at least 3 ft. between standing vehicles.
4. Where carriageway markings are necessary they should conform to the appropriate regulations for white line markings and lettering.

Fig. 4–5 Layouts of lay-bys and bus bays

Those parts of the footway immediately adjoining buildings, fences, trees and other obstructions will not be available for the free movement of pedestrians and should be disregarded when calculating the width required. Minimum clearances between the edge of the carriageway and obstructions on the footway are specified in Table 4–2. The capacity of open footways may be taken as 10 to 15 persons per foot width of pavement per minute after deducting approximately 3 ft. 'dead width' in shopping areas and 1 ft. 6 in. elsewhere.

Recommended footway widths for various types of road are given in Table 4–3. Greater widths may be necessary where pedestrian traffic is heavy or additional space is required for underground services.

Table 4–3 Recommended footway widths

Type of road	Recommended minimum footway widths
Primary distributor:	
Urban motorway	No footways
All-purpose road	9 ft.*
District distributor	9 ft. in principal business and industrial districts* 8 ft. in residential districts*
Local distributor	9 ft. in principal business and industrial districts* 6 ft. in residential districts*
Access road	Principal means of access: 9 ft. in principal business districts.* 6 ft. in industrial districts* 6 ft. normally in residential districts* 12–15 ft. adjoining shopping frontages Secondary means of access: 3 ft. verge instead of footway on roads in principal business and industrial districts 2 ft. verge instead of footway on roads in residential districts

*If no footway is required provide verge at least 3 ft. wide

Footways adjoining short shopping frontages (e.g. in residential streets) should be at least 12 ft. wide; a minimum of 15 ft. is desirable adjoining longer shopping frontages such as those in the town centre. These footways will usually have to accommodate more pedestrians and perambulators than any others, and it is important that they should be wide enough for free movement and for shop window gazing without risk of being jostled.

At points of possible congestion such as bus stops and the entrances to large shops and public buildings it may be necessary to widen the footway by setting back the frontage line or arcading the buildings. It will often be useful to design bus queue shelters so that pedestrians can walk through them when there are no people waiting. Passenger shelters with seats should usually be located at the back of the footway or behind the highway boundary.

Where space is available for a more generous layout the provision of a verge between the footway and the carriageway will add to the safety of pedestrians by increasing their separation from moving vehicles. Verge widths and construction are considered in Section 4.4. When deciding the width required for footways and verges, that needed to accommodate underground services clear of the carriageways should also be taken into account (see Section 7.3).

The erection of pedestrian guard rails along the edge of the verge or footway will give effective segregation but may lead to access difficulties, especially where premises have no secondary means of access. Possibly the most useful function of guard rails is the guidance and protection of pedestrians at points of special danger such as busy road junctions. Pedestrian guard rails should be neat and simple in appearance; their height and construction should deter children from climbing through or over them.

4.2.2 Elevated footways

Elevated footways offer opportunities for imaginative architectural design and are being included in a number of important development projects. They ensure complete segregation of pedestrians from vehicles and enable wider carriageways to be constructed at ground level. Their width should be calculated in the same way as for those at ground level, and the same minimum standards should apply; care should be taken to avoid giving pedestrians any sense of restriction. If elevated footways are located above the carriageway there must be at least 16 ft. 6 in. headroom for vehicles, and the appropriate clearances must be maintained between the carriageway and any supports for the footway. Where elevated footways are situated outside the highway boundary (e.g. on the podium of a building) they may be at some other level, provided adequate headroom is available at any vehicular access to the building. Even though no footways may be needed at ground level, kerbed and paved margins at least 3 ft. wide should be constructed alongside the carriageway to protect buildings abutting the road and for the use of police and maintenance staff.

Appropriate arrangements will be needed for the drainage of elevated footways to ensure that water does not run on to the vehicles below. Parapets should be high enough and so constructed as to deter children from climbing through or over them. For safety, parapets need to be at least 3 ft. 3 in. high, but to avoid an unduly heavy appearance they should preferably not be higher than 4 ft.

Elevated footways should be inter-connected by bridges across the road at suitable intervals. Access to ground level should be provided at bus stops and other convenient points by means of ramps, stairs or escalators.

4.2.3 Arcading over footways

The upper storeys of buildings may be allowed to project forward over the public footway provided daylighting and sunlighting standards can be maintained, minimum headroom of 16 ft. 6 in. can be obtained over the full highway width and no supporting columns or piers are required within this width.

It will sometimes be possible to recess shop fronts behind the highway boundary, thereby increasing the width of the footway and protecting shoppers in bad weather. Alternatively, protection can be given by canopies projecting over the footway; these should be cantilevered from the buildings to avoid the need for supports obstructing the footway. Canopies should have adequate clearance from the edge of the carriageway in accordance with Table 4–2.

4.2.4 Pedestrian arcades

Arcades have the advantages of enabling people to do their shopping under cover and of keeping them away from moving vehicles. Arcades should preferably be at least 20 ft. wide and, for maximum effectiveness, should be sited on or between main

Walk-through queue shelters

. . . Pedestrian guard rails should be neat and simple in appearance, their height and construction should deter children from climbing through or over them

Elevated footway system with linking bridges, London Wall

Buildings cantilevered over the footway provide weather protection for shoppers

Subway with ramped approaches as well as steps

Shops can help to make subways more attractive

It is often useful to site pedestrian subways in conjunction with bus stops

pedestrian routes. They should be served by back streets for goods delivery and should have car parks near at hand for the convenience of customers and to avoid congestion in nearby streets

4.2.5 Pedestrian ways

These should be planned as a secondary network of streets for pedestrians only, thereby ensuring that those who use them are segregated from vehicular traffic. They will be useful not only in shopping and business precincts but also in residential areas, where they should be planned to give direct and convenient access from houses to shops, schools, open spaces, etc. independently of the general road system. They should be linked to coach and bus stops and railway stations.

It is important that pedestrian ways should be suitably wide, especially at points where pedestrians are likely to congregate. In business areas they should usually be at least 20 ft. wide and in residential areas at least 6 ft. wide. Where necessary they should be carried over or under any roads which they cross.

4.2.6 Pedestrian bridges and subways

Bridges or subways solely for the use of pedestrians will be required as part of a pedestrian way system and at busy junctions and other points where pedestrians need to cross the road in large numbers. As pedestrian bridges and subways are usually fairly short and are intended solely for movement they can reasonably be assumed to have a higher acceptable capacity than ordinary footways, but flows should not exceed 27 persons per foot width per minute on the level and 19 persons per foot width per minute on stairs or ramps. A 'dead width' of about 2 ft. 6 in. is usually allowed adjoining any display windows in subways.

Where possible, bridges and subways should have ramped approaches as well as steps. Continuous ramps should preferably not be steeper than 1 in 10. Consideration should be given to the possible need for a surface-heating system to obviate hazards due to snow and ice where steeper gradients are necessary. Bridges should have clear headroom of 16 ft. 6 in. above the carriageway and in the case of permanent structures a deck width of at least 6 ft Subways should have a minimum width of 7 ft. 6 in. and at least 7 ft. headroom for pedestrians. They should be attractive in appearance and, for public confidence and safety, should have straight and well-lit passageways free from recesses.

To ensure the maximum effectiveness of these expensive facilities their use should not involve long detours or unnecessary climbing. Bridges are generally cheaper than subways but usually require more climbing. Construction of subways across existing streets may involve heavy expenditure on the diversion and regrading of services; underground services in new roads should be located so that proposed subways can be kept as shallow as possible.

It may sometimes be possible to minimise interference to services and reduce the number of steps to be climbed by raising the level of the carriageway over a subway.

Where possible, pedestrian subways or bridges should be sited in conjunction with bus stops.

4.2.7 Crossing the carriageway

Pedestrians who cross the carriageway at random are in far more danger than those who do so at recognised crossing places. If the construction of special bridges or subways across busy streets is impracticable or cannot be justified, pedestrians should be guided and encouraged to cross the carriageway at a limited number of clearly recognisable points where they can do so in

safety and with the least possible interference to other traffic Pedestrian crossings, either controlled or uncontrolled, or refuges should be provided at appropriate points to assist pedestrians in crossing the road. The greatest need to cross the carriageway is likely to occur at junctions; the siting of refuges and ways of simplifying traffic movements at junctions are considered in Chapter 10

Although the safest place to cross the carriageway is at signal-controlled or zebra crossings there is evidence that the risk of crossing within 50 yards or so of these points is exceptionally high. To encourage the safe and proper use of crossings it will often be helpful to erect pedestrian guard rails on the approaches

Although guard rails have great value at points of special danger it is not considered that there is sufficient justification for their universal erection, which might be unduly confining and would create difficulties on narrow footways and at shops, bus stops and vehicular accesses. Control by less obvious means can often be exercised by the planting of hedges and shrubs along the verges and central reserve, or by the erection of a suitably deterring fence or wall along the reserve. It is important that these features should not restrict visibility on bends or at junctions or conceal pedestrians at crossing places.

Guard rails are particularly useful for preventing heedless walking or running into the carriageway from passageways, school exits, etc.

A low fence, suitably designed, can effectively deter pedestrians from crossing the central reserve at random

Fences should not restrict visibility at bends or junctions, or conceal pedestrians at crossing places

4.3 Cycle tracks and cycle ways

The volume of cycle traffic is declining in many parts of the country, but in some towns cyclists are still present in sufficient numbers to have an important influence on highway requirements.

Provision of cycle tracks will not be appropriate on *district* and *local distributors* and *access roads* where the speed of traffic is relatively low, though the widening of the nearside traffic lanes to 14 ft. may be warranted where cycle traffic is heavy. Widening of the nearside lanes may also be required on all-purpose *primary distributors*, but in view of the vulnerability of cyclists arrangements should be made where possible to route them along quieter roads. Where no alternative routes are available and the number of cyclists exceeds 1,500 in a 16-hour period or where heavy cycle traffic may be expected at certain times of the day (as, for example, near an industrial estate) consideration should be given to the provision of cycle tracks or cycle ways.

Cycle tracks should normally be designed for one-way traffic, though two-way operation may sometimes be necessary. For one-way traffic the standard width is 9 ft. and the minimum 6 ft. If cycle traffic warrants a width in excess of 9 ft. the increase should be by units of 3 ft. For two-way operation the normal minimum should be 12 ft., but lesser widths will be acceptable when flows are light.

Cycle tracks should have a well-maintained and carefully graded surface. Their profile should continue without interruption across intersecting vehicular entrances; gently sloping ramps and lowered kerbs should be provided where they join the carriageway. To ensure the rapid dispersal of surface water they should have a crossfall of about 1 in 40 and should be equipped with gullies at appropriate intervals. A cycle track should desirably be separated from the carriageway by a verge about 6 ft. wide and from the footway by one at least 3 ft. wide. Where space is limited any modification of width should first be effected between the cycle track and footway; if this verge has to be omitted a low kerb may be used as a delineator. The verge between the cycle track and the carriageway should not be narrower than 3 ft.

At busy single-level junctions with a high proportion of cycle traffic (especially right-turning traffic) the construction of cycle subways may be warranted. These should have at least 7 ft. 6 in. headroom and a minimum width of 10 ft. 6 in. for one-way working or 13 ft. 6 in. for two-way working. Maximum ramp gradients should be 1 in 20 upwards and 1 in 15 downwards.

Consideration should be given to the possible need for subways for the combined use of pedestrians and cyclists. Combined subways should have at least 7 ft. 6 in. headroom and a minimum width of 16 ft. 6 in. for one-way cycle traffic or 19 ft. 6 in. for two-way traffic; these widths include a single 6 ft. footway.

Where cycle traffic is heavy or concentrations of cyclists occur (as, for example, between a housing estate and a factory or school) it may sometimes be desirable to construct cycle ways. These should be wide enough for two-way traffic. They should be separate from the general road system and should cross other roads at a different level. It may be possible to combine cycle ways with the pedestrian way system.

4.4 Verges

4.4.1 On all-purpose roads

On all-purpose roads in principal business and industrial districts the full width between the carriageway and the highway boundary will usually be paved and used as a footway. Where, however, restrictions on space are less severe the inclusion of verges will not only increase the separation of vehicles from pedestrians but may improve the appearance of the road.

Verges less than 6 ft. wide should normally have an attractively coloured and textured stone surface with a cobbled, surface-dressed or other suitably bound finish. A crossfall of about 1 in 30 will usually suffice for verges of this type. Wider verges may be grassed, provided their width is sufficient for the establishment and maintenance of grass cover. Grass verges may require a crossfall of about 1 in 20 for adequate drainage, they should be suitably levelled and trimmed, and should be free from concealed grips and similar hazards.

On roads without footways and cycle tracks, verges will be required between the carriageway and the highway boundaries, not only to accommodate lighting columns, traffic signs, underground services, etc., but to provide appropriate clearance to ensure proper vehicle placement and development of full carriageway capacity. On all-purpose roads the normal minimum width should be 3 ft., but this may be reduced to 2 ft. on secondary access roads in residential areas. The clearance between the carriageway and any obstruction on the verge should be in accordance with Table 4–2.

Cuttings and embankments within the highway limits will normally be grass covered. The appearance and stability of the slopes will be improved by rounding them at the top and bottom and by planting them with suitable shrubs. Where the carriageway is on an embankment above footways or cycle tracks, safety fencing may be needed at the top of the embankment.

4.4.2 On urban motorways

In view of the higher speed of traffic on urban motorways, wider verges are desirable

(i) to obtain maximum capacity by increasing the lateral clearances to fixed obstructions, and

(ii) to provide at least partial shelter for broken-down vehicles without interfering with the stable flow in lanes past them.

Where space is restricted and costs of acquisition and construction are high a minimum width of 5 ft. can be tolerated, but where conditions are easier the widening of the verge to 8 ft. will ensure greater safety and allow more adequately for maintenance functions and the siting of drains and services.

Verges should be paved and flush with the carriageways. To ensure that the verges are clearly distinguishable they should be separated from the carriageways by white marginal strip markings 1 ft. wide and should preferably have a contrasting colour and texture. The full width of paved verges should remain unobstructed by street furniture.

As indicated in Sub-Section 4.1.10, lay-bys will be required at intervals of not more than half a mile along each carriageway on those lengths of urban motorway where it is impracticable even to provide paved verges 5 ft. wide. Where lesser clearances are unavoidable they should be in accordance with Table 4–2, and raised kerbs should be used instead of flush marginal strips.

4.5 Use of suitable materials

The materials used in road construction should harmonise with their surroundings, local materials being used wherever possible. Variations of colour and texture in the surfacing of the carriageways, cycle tracks and footways can add to the appearance and safety of the road. Providing their wearing quality and skid resistance are adequate, there is considerable advantage in using light-coloured rather than dark aggregates for the road surface; they reveal obstructions more readily and aid visibility at night. The colour and texture of the road surface should be uniform over as long a length as possible. To avoid the creation of ugly scars, repairs should be carried out with materials matching those originally used.

Part of the 14-mile system of cycle and pedestrian ways at Stevenage

Subway for cyclists and pedestrians under roundabout

Where space permits, wide verges can be an attractive feature of the urban scene

Boundary walls, fences and hedges provided in the course of roadworks should have a good appearance and be in keeping with the locality. They should be designed to give the required degree of physical separation without creating a tunnel effect or preventing the integration of the road into its surroundings. Low walls and light, open fences or railings will often suffice, but on urban motorways more-substantial barriers may be required to deter trespassers.

4.6 Variation of layout

In built-up areas the various paved components of the road have, within narrow limits, to be parallel to one another, but where some variation can be made a pleasing effect may result. For example, it may be possible to vary the position and level of the footway, provided the alterations do not induce pedestrians to take undesirable short cuts. Variation of the verge width may sometimes give scope for the planting of trees and shrubs, but care should be taken to prevent or discourage the use of the verge by pedestrians, and it should never be so narrow as to make maintenance difficult. It may sometimes be possible to save a line of trees or other attractive features by slight variations of alignment or layout, e.g. by placing the footway behind the trees. On sidelong ground it may be advantageous for both appearance and economy to have the carriageways, footways and cycle tracks (if any) at different levels.

Trees saved by means of wide, raised central reserve

4.7 Typical cross-sections

4.7.1 *Primary distributors*—urban motorways

Typical cross-sections	Fig 4–6.
Design speed	50 mph normally, 40 mph where alignment is restricted.
Carriageways	Normally dual two- or three-lane layout with 12 ft. traffic lanes.
Central reserve	10 ft. standard and 6 ft. minimum width with central safety fence 2 ft. wide. Increase width as necessary at other obstructions to provide clearances in accordance with Table 4–2 and appropriate visibility on inside of bends.
Marginal strip markings	Standard width 12 in.
Verges	Paved, flush with carriageways and not less than 5 ft. wide. Desirable width 8 ft where conditions permit. For alternative arrangements where width is severely restricted, see Sub-Section 4.4.2.

4.7.2 *Primary distributors*—all-purpose

Typical cross-sections	Fig. 4–7.
Design speed	40 mph normally.
Carriageways	Normally dual two- or three-lane layout with 12 ft. traffic lanes. A single-carriageway layout will be appropriate if one-way operation is envisaged.
Central reserve	6 ft. standard and 4 ft. minimum width if unobstructed. 11 ft. standard and 7 ft. absolute minimum width with lighting columns. 16 ft desirable minimum to accommodate lane for right-turning traffic approaching an intersection.
Footways	Consider possible routeing away from road. 9 ft. minimum width where essential.
Cycle tracks	9 ft. standard and 6 ft. minimum for one-way operation. 12 ft normal minimum for two-way operation.
Verges	3 ft. minimum if provided instead of footway, but consider width needed for traffic signs, underground services, etc. and clearances in accordance with Table 4–2. 6 ft. desirable minimum and 3 ft. absolute minimum between carriageway and cycle track. 3 ft. desirable minimum between cycle track and footway, but use low kerb where space is restricted.

4.7.3 *District distributors*

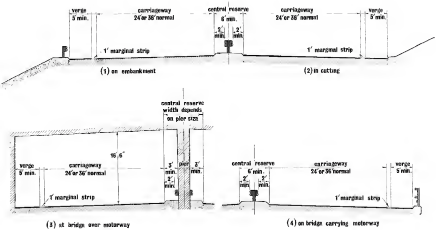
Typical cross-sections	Fig. 4–8.
Carriageway lane widths	12 ft. standard. 11 ft. on roads with four or more lanes if proportion of heavy commercial traffic is fairly low.
Carriageway layout	Residential districts: single two-lane layout where practicable, but traffic volumes will often warrant dual carriageways. Principal business and industrial districts. dual two-lane carriageways normally. In all districts one-way systems with single carriageways will sometimes be appropriate.
Central reserve	6 ft. standard and 4 ft. minimum width. Increase clearances to lighting columns, etc. as indicated in Table 4–2 where carriageways are superelevated. 15–16 ft. desirable minimum to accommodate lane for right-turning traffic approaching an intersection.
Footways	9 ft. minimum in principal business and industrial districts. 8 ft. minimum in residential districts.
Verges	3 ft. minimum if provided instead of footway, but consider width needed for traffic signs, underground services, etc. and clearances in accordance with Table 4–2.

4.7.4 *Local distributors*

Typical cross-section	Fig. 4–9.
Carriageway lane widths	12 ft. in industrial districts. 11 ft. in principal business districts. 10 ft. in residential districts.
Carriageway layout	Single two-lane.
Footways	9 ft. minimum in principal business and industrial districts. 6 ft. minimum in residential districts.
Verges	3 ft. minimum if provided instead of footway, but consider width needed for traffic signs, underground services, etc and clearances in accordance with Table 4–2.

4.7.5 *Access roads*

Typical cross-sections	Fig. 4–10.
Carriageway lane widths	9 ft. to 12 ft. normally (for details see Table 4–1).
Carriageway layout	Single two-lane.
Footways	6 ft. to 15 ft. (for details see Table 4–3).
Verges	3 ft. minimum if provided instead of footway (2 ft. on secondary *access roads* in residential districts), but consider width needed for traffic signs, underground services, etc. and clearances in accordance with Table 4–2.



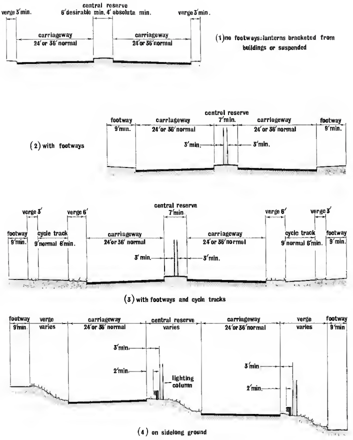
Notes:

1. The central reserve should be bordered by raised kerbs where it is 6 ft wide or less, or where the face of any safety fence is less than 4 ft from the adjoining carriageway. Where greater widths are available, flush marginal strips 1 ft wide may be used instead of kerbs.

2. On lengths of motorway without paved verges the nearside edge of each carriageway should be bordered by raised kerbs and should be at least 2 ft clear of the face of any safety fence on the verge and at least 3 ft clear of bridge piers, retaining walls, lighting columns, etc.

3. The clearance between the carriageways and any fixed obstructions on the inside of bends at the sides of the road or on the central reserve should be increased where necessary to ensure the requisite visibility standards.

Fig. 4-6 ***Primary distributors*****—urban motorways. Typical cross-sections**



The clearances shown above are suitable for speeds above 30 mph.
As indicated in Table 4–2 lesser clearances may be used on roads designed for 30 mph.

Fig. 4-7 *Primary distributors*—all-purpose roads. Typical cross-sections

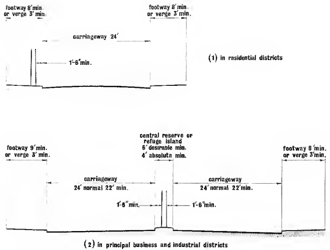


Fig. 4–8 *District distributors.* Typical cross-sections

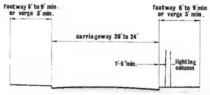
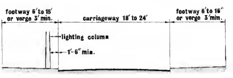
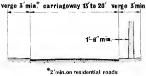


Fig. 4–9 *Local distributors.* Typical cross-section



(1) principal means of access



(2) secondary means of access

Fig. 4–10 *Access roads.* Typical cross-sections

5 Road equipment and other features

5.1 Street lighting

Recommendations on the design of street lighting installations are given in British Standard Code of Practice C.P.1004, which is at present being revised. Parts 1 and 2 of the revised version were published in 1963[10]; Part 1 describes the general principles of lighting and Part 2 the lighting of traffic routes. Further parts will be published later dealing with the lighting of roads carrying only local traffic, roundabouts and complex junctions, bridges and flyovers, tunnels and underpasses, roads with special requirements, and town centres.

Lighting installations must be efficient by night and should look well by day. No hard-and-fast rules can be given to ensure aesthetically satisfactory design and layout; every town and village has its own character, but it should be possible to meet most requirements within the general principles and tolerances of the Code. The design of lighting installations for streets bordered by buildings of architectural or historic interest will require particular care.

Useful guidance on the design and siting of lighting columns is given in the Code. As well as being arranged to give satisfactory light distribution, columns should be sited to minimise obstruction of the footway, protect sight lines and ensure the necessary clearances from the carriageway. The minimum width of the central reserve and footways may be affected by the presence of lighting columns and the clearances from the carriageway recommended in Table 4–2.

The texture and colour of the road surface will influence the effectiveness of a lighting installation, and where cost, durability and skid resistance permit it is an advantage to the lighting to use a light-coloured road surface.

On distributor roads of all types, lighting will be required primarily to facilitate the safe movement of traffic (including pedestrians and cyclists on all-purpose roads). The recommendations given in Part 2 of the Code will be widely applicable to these roads and their adoption should make for uniformity of standard and quality. On any given traffic route the lighting should be of uniform standard and frequent changes in the type of lighting should be avoided.

On *access roads*, lighting will usually be required more for amenity and security purposes than for traffic movement. The standard of lighting will depend on the type of street; a standard lower than that needed for traffic routes will suffice for quiet streets in residential areas, but for the busy streets of shopping and business districts a high standard of lighting will be necessary.

5.2 Traffic signs

On busy urban roads clear signposting is essential to prevent indecision, confusion and danger. Signposting requirements may present special problems where space is restricted and should always be considered at an early stage in planning road improvements or new roads.

Traffic signs should conform to the appropriate statutory instruments and Departmental recommendations.[11] They should be clearly visible, and the letter sizes should be appropriate to the speed of traffic and the displacement of the signs from the driver's path. They should be located so as to allow ample opportunity for any necessary action or manoeuvre. Their number should be kept to the minimum required for the proper guidance and control of traffic.

With the exception of waiting restriction signs and certain other prescribed types, all warning, mandatory, prohibitory and advance direction signs should be illuminated by direct lighting where they are located within 50 yards of a street lamp; if further away they may be either illuminated by direct lighting or reflectorised. Many informatory signs do not warrant the expense of direct lighting (e.g. toilet and parking signs) but should be placed where they can be seen after dark by the light from nearby street lamps. To ensure efficient operation and reduce cable and duct costs, sign and street lighting installations should be designed together wherever possible. The control system should enable lighting to be switched on quickly if daytime visibility deteriorates. It may be desirable for some signs and bollards to remain lighted throughout the day.

It may sometimes be necessary to erect signs on the central reserve, duplicating those at the side of the road. On roads where traffic is so heavy that there is a risk of roadside signs being hidden from view, illuminated overhead signs may be more suitable. Special gantries will be required to support these signs, though it may sometimes be possible to mount them on bridges over the road. Overhead signs are especially useful to indicate lane positions on the approaches to busy junctions.

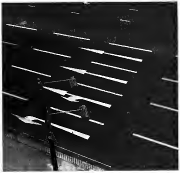
To avoid congestion and danger on heavily trafficked urban motorways, special arrangements may be required to give advance warning of accidents, weather hazards, and road or lane closures. Warning may be given by means of a system of overhead illuminated signs spaced at intervals of not more than one mile; as indicated in Section 5.4 it may be convenient for the signs to be switched on and off from the emergency telephone control point. Where bridges are conveniently located, it may be preferable to mount warning signs on bridge parapets rather than to erect special gantries. At the site of an accident additional guidance to traffic should be given as quickly as possible by the erection of portable warning signs in accordance with Departmental requirements.

5.3 Carriageway markings

Safe and orderly use of the carriageway should be encouraged by the provision of carriageway markings in accordance with the appropriate statutory instruments and Departmental regulations.[11] Markings should be used not only to define traffic lanes but to guide vehicles at junctions and indicate the positions of bus stops, taxi ranks, waiting lanes and parking bays. To reduce the number of traffic signs, yellow markings may now be used at the edge of the carriageway to denote waiting restrictions.

Carriageway markings should be skid-resistant in both wet and dry weather conditions. Adequate skid resistance is particularly important where the camber or crossfall is steep and at junctions where turning traffic includes an appreciable number of two-wheeled vehicles.

Sign gantries can often be of relatively light construction



Clear carriageway markings are particularly helpful on the approaches to junctions

Television surveillance by remote control of Motorway M.4, London

Double white lines should not be needed on properly designed new roads in towns. They are not regarded as suitable for general use on existing urban roads because of the possibility of standing vehicles, but there may be sites with restricted visibility where their use is justified. They should not be used merely to displace standing vehicles; 'No Waiting' Orders will be appropriate in such circumstances.

Reflecting studs will not usually be required on urban roads in addition to carriageway markings. In certain areas, however, the risk of fog or poor visibility may be high enough to justify their installation, even though the street lighting may be adequate for normal conditions.

5.4 Emergency telephones

These are only appropriate on motorways, where segregation from the ordinary road system makes it difficult for a driver to summon aid in the event of an accident or breakdown. To enable aid to be obtained quickly, emergency telephones should be provided on both sides of the road at intervals of not more than half a mile, or at each lay-by on lengths without paved verges. Telephones should be solely for emergency use and should be connected to a central control point.

It will usually be convenient for the emergency warning signs to be actuated from the same central control. This will enable the appropriate signs to be switched on as soon as details of the emergency are received by telephone.

5.5 Safety fences

In towns the main need for safety fences for the protection of vehicles will arise on urban motorways and other *primary distributors* where speeds are high. Except at points of special danger, safety fences will not usually be required on all-purpose roads subject to a 30 mph speed limit.

On urban motorways and where necessary on all-purpose *primary distributors* safety fences should be erected:

(i) on both sides of the road on embankments 20 ft. high or more;
(ii) on the outer edge of the road where the radius is 2,600 ft. or less and the embankment height 10 ft. or more.

These minimum heights do not preclude the placing of continuous lengths of safety fencing along embankments whose height is slightly less than these figures at certain points.

Safety fences may also be needed at other danger points, e.g. where there is a road, railway or river at the foot of an embankment, where the road is supported by high retaining walls, on bridges with lightly built parapets, or in advance of bridge piers or other obstructions on the central reserve or verges.

In advance of obstructions on the verges or central reserve, safety fences should be aligned at a narrow angle to the road so as to deflect vehicles away from the obstruction. Where reserves are narrow and speeds high, continuous safety fencing may be required both to screen obstructions and to prevent accidents due to vehicles crossing the reserve.

Safety fences should normally be unobtrusive in appearance, but at points where attention needs to be drawn to special dangers, e.g. on the outside of a sharp curve, it may be helpful to paint black and white bands 3 ft. wide on the fenders.

Safety fence on central reserve in advance of bridge piers

Double safety fence under construction on the narrow central reserve of an urban motorway

5.6 Street furniture

The choice of street furniture requires discrimination and care. Useful guidance may be obtained from the Council of Industrial Design publication *Street Furniture from Design Index 1965/66*.[12]

Street furniture should not be allowed to obstruct sight lines or encroach on carriageway clearances. If placed too near the carriageway street furniture may lead to accidents by restricting the view of pedestrians about to cross the road. Obstruction of the footway should be avoided wherever possible by siting equipment behind it or on the verge (provided the verge is wide enough)

Seats placed by the roadside constitute a welcome amenity for pedestrians but should not be allowed to obstruct the footway. They should preferably be placed on the verge (if wide enough) or in recesses along the boundary line. The ground in front of the seats should of course be suitably hardened and drained.

Bins for the storage of sand and grit should not be sited where they obstruct the footway or where loading operations may interfere with the flow of traffic. If possible they should be sited on the verge at lay-bys or in well-lighted positions on *local distributors* or *access roads*.

To encourage the public to keep the streets clean and tidy, plenty of litter baskets or bins should be provided. Many attractive designs are now available which keep litter hidden from view and protected from the wind and rain. Bins should be attached to lamp standards or sited where they do not obstruct the footway but can easily be seen.

Telephone kiosks, pillar boxes and police call boxes must necessarily be placed where they are conspicuous, but they should neither restrict the movement of pedestrians nor limit visibility at junctions or on bends. It will often be possible to site them behind the footway or on wide verges. Where possible, telephone kiosks and post boxes should be sited adjoining lay-bys. Fire alarms in boxes fixed to boundary walls will cause less obstruction than those mounted on posts.

Public conveniences should not be located on roundabouts or traffic islands unless access is obtained solely by subway. Conveniences will be more easily accessible if placed above ground with entrances at the back of the footway.

Street name plates should be well designed and clearly lettered. To ensure that they can easily be seen by all road users they should be placed not more than 10 ft. from street corners. They should be placed on both sides of side streets to facilitate identification from the main road. On long roads they should be placed at all intersections and at intervals of not more than 200 yards in between. The lower they are fixed the more easily they can usually be seen, but in busy streets they will need to be at least 6 ft. 6 in. above the ground to avoid being obscured by vehicles and pedestrians. Elsewhere a lower mounting height may be suitable and should enable name plates to be seen from vehicles with side-lights or dipped headlights. Name plates should not be less than 2 ft. from the ground and should preferably be fixed so that they will be illuminated by street lamps. Street names can also be conveniently indicated on the side panels of bollards.

All houses, offices, business establishments and other premises should be numbered, and their numbers should be displayed on their gates or doors so as to be clearly visible from the street. Numbers should be arranged so that when travelling away from the centre of a town the odd numbers are on the left and the even numbers on the right. Succeeding numbers should be approximately opposite one another, even though this may require the omission of certain numbers or the use of suffix letters where frontages vary.

Irregularities in the boundary line will enable seats to be placed clear of the footway

5.7 Trees and shrubs

When improving existing roads or building new ones, existing trees and shrubs should be retained wherever possible. Where space is restricted the only possible form of planting may be the

avenue, but this can be unsatisfactory without focal points. It may be better to concentrate available land on one side of the road and plant a single row of trees, or to utilise any irregularities in the fence line for planting in groups. A spacious appearance can be given to the road by planting between the footway and the boundary, or beyond the boundary if the land is in the ownership of the local authority. Planting should normally be informal, but formal treatment may be required in certain places, as, for example, near a civic centre.

Trees should be chosen and sited so that they will not outgrow their positions, damage surfacing or underground services, overshadow adjoining buildings or require frequent pruning. Varieties which are liable to shed branches should not be selected. Trees which shed large leaves should not be planted close to the carriageway.

Trees and shrubs should never be planted where they might interfere with visibility; they should be set back a sufficient distance from the edge of the carriageway to allow for growth without prejudicing minimum clearances. If the road is likely to be widened in the future they should if possible be located where they will not be disturbed.

A dense plantation of trees and shrubs between the road and adjoining development may be useful as both a visual screen and a baffle against noise and dust.

Useful information on the choice, siting and maintenance of trees is given in the Ministry of Housing and Local Government publication *Trees in Town and City*.[15]

5.8 Roadside advertisements

Full guidance on the safety aspects of the control of roadside advertisements is given in Circular No. 11/62 issued by the Ministry of Housing and Local Government.[14] On motorways, only authorised traffic signs are permitted, but some advertisements may be allowed within service areas. It is obviously desirable that no advertisements likely to constitute a danger to traffic or to be detrimental to amenity should be erected on land adjacent to urban motorways and other distributor roads.

Trees add much to the attractiveness of this shopping centre

Roadside garden with steps leading to elevated footway system at London Wall

6 Structures

In the preliminary stages of establishing the line of a road in plan and profile, consideration should be given to the structures which will be required and to the economic, structural and aesthetic aspects of their design and construction. Bridges and tunnels should fit into the general road alignment, but their siting—especially in the case of major structures—may have an important bearing on the choice of route. A booklet on the appearance of bridges has recently been prepared by the Ministry of Transport with the assistance of the Royal Fine Art Commission.[25]

Bridges with curves or excessive skews, or founded on poor ground, are likely to prove difficult and costly to construct. Careful choice of route and some realignment of existing roads can often avoid these problems.

6.1 Bridge loadings

Bridges should be designed to carry the loadings specified in Ministry of Transport Memorandum No. 771: *Standard Highway Loadings*.[26] Details of the standard loadings are given in Appendix A of British Standard 153, Part 3, Section A, 1954.[27]

6.2 Bridges over the road

Minimum clearances between the carriageway and the faces of abutments or piers are specified in Table 4–2. Minimum headroom of 16 ft. 6 in. must be provided and maintained over the carriageways and normally over paved verges (if any).

Bridge piers should be sufficiently robust to withstand possible vehicle impacts. When economically justifiable there should be no piers on the central reserve.

Where the road is in cutting and the bridge is of typical three- or four-span construction the slopes of the cutting should continue unchanged under the bridge. Slopes under bridges should be suitably paved with material in keeping with the appearance of the bridge.

6.3 Bridges carrying the road

Small-span bridges should be unobtrusive; where they are of the buried-culvert type the embankment should be carried through at full formation width.

Consideration should be given to possible advantages of designing bridges carrying dual carriageways with a separate structure for each carriageway. The two decks need not be widely separated, as the main economy can be achieved by breaking the transverse continuity. Open gaps between the structures can be achieved by covering with slats or open grids designed to withstand Type HA loading, as described in B.S. 153, Part 3, Section A, 1954.[27] Where light wells are provided they should be protected by safety fences together with parapets matching those on the nearside.

The crossfall or superelevation of carriageways on bridges should conform to the normal standards for the road. Similarly, the footways, hard shoulders and central reserve should be constructed to the standard crossfalls. The whole of the deck area including the verges and central reserve should be paved to prevent the ingress of water, and no earth should be allowed to encroach on the structure.

Consideration should be given to the possible need for electrical road heating on bridges and viaducts which may be particularly vulnerable to icing.

Bridges carrying the road over a railway should be designed to minimise possessions of the line during construction. The slowing-down of trains can often be avoided by providing greater

Hammersmith Flyover

Temporary flyover at a congested junction in Birmingham

lateral clearances than the minimum demanded, and this may prove cheaper than using the minimum standards. The parapets must normally be of solid construction 4 ft high, or 5 ft high on bridges over railways electrified on the overhead system.

6.4 Tunnels

Tunnels are expensive to construct, drain and maintain, but it may sometimes be possible to meet at least part of their extra cost by permitting development to take place above them. The lighting of tunnel entrances and exits requires particular attention to ensure safe transitions between daylight and artificial lighting. The ventilation systems needed in long tunnels are costly to install and maintain. Ventilation must be adequate to cope with conditions arising from traffic congestion.

Roads in tunnel should usually conform to the normal design standards, but lower standards may be warranted in special cases. For example, at some junctions it may be advantageous to construct special tunnels with steeper gradients and lower headroom than normal solely for cars and other light motor vehicles, thereby affording sufficient relief to certain traffic streams to obviate the need for more costly and elaborate improvements.

The high cost of tunnel construction may make it impracticable to provide paved verges on urban motorways passing through long tunnels; in such cases lay-bys should be provided instead for emergency use.

Hyde Park Corner Underpass

Tramway tunnel converted for the use of cars and other light vehicles proceeding from Waterloo Bridge to Kingsway, London

7 Sewers and public utility services

7.1 Surface water drainage

Recommended procedures for the application of the 'rational' (Lloyd Davies) formula and the Road Research Laboratory hydrograph method to the design of surface water sewerage systems are given in Road Note No. 35: *A guide for engineers to the design of storm sewer systems*.[18] The Note includes results of the work of the Hydraulics Research Station on the flow characteristics of sewers.

Crossfalls of carriageways, footways, etc., should be sufficient to ensure the rapid drainage of surface water without causing discomfort or danger to road users. Recommended crossfalls are given in Chapter 4. Surface water should normally be collected by means of gullies and discharged through a piped drainage system. Gullies should preferably be placed behind the kerb and should have side-entrance gratings. Gully gratings in the channels may be necessary, however, if the space behind the kerb is occupied by other underground services or if the steepness of the gradient precludes effective drainage by recessed or weir-type gullies. Suitable arrangements should be made for collecting surface water at changes of crossfall such as those arising from the introduction of superelevation.

Where the road is in cutting, French drains may be needed to intercept soil water and lower the water table under the road. French drains may also be required along grass-covered central reserves with a dished cross-section. Where French drains discharge into sewers, care should be taken to avoid their being flooded if the sewers become surcharged.

Special attention should be given to the drainage of underpasses, subways, cuttings, valley curves and other points where flooding might cause serious difficulties. The possible need for storm water storage and pumping should be considered. Drainage design for such situations should be sufficiently generous to cope with heavy storms.

7.2 Location of sewers

Surface water and foul sewers will usually be laid under the carriageway; there is little risk of interference to traffic as sewers rarely need to be uncovered for repairs. Where, however, there is a wide central reserve or the footways and verges are wide enough to accommodate sewers as well as other services, consideration should be given to siting the sewers clear of the carriageway. Main sewers should preferably be routed along streets of little traffic importance and through open spaces.

As sewers are normally laid in straight lines between manholes, their distance from the side of the road will depend upon road curvature. Clearances should always be sufficient for the accommodation of other services at the side of the road. Sewers should be deep enough to ensure that branch connections can be made without interference to other services. Where roads are wide and many branches are needed the duplication of sewers may be justified to shorten the connections and reduce the risk of having to open the road for repairs.

7.3 Public utility services

Public utility services are essential to the life of the community, but their proliferation has made the problem of accommodating them within the highway extremely difficult. Furthermore, repair and maintenance operations often hinder traffic and accelerate the deterioration of the road structure.

Although any attempt to rationalise the positions of services in existing streets would be impracticable because of the high cost and interruption to traffic it is important that the positions of underground mains should be accurately recorded to facilitate repair work and minimise obstruction and traffic delays.

The construction of new roads or the improvement of existing ones will afford opportunities for the orderly accommodation of services under the footways and verges instead of under the carriageways. The laying of distribution mains in duplicate, one on each side of the road, will obviate the need for lengthy service connections under the carriageway; this will be advantageous to traffic and often more economical to the undertakers. Where, however, it is necessary for service connections to cross the road they should be laid before the carriageway is constructed.

As recommended in a report published by the Institution of Civil Engineers,[19] mains should normally be located in the following order between the highway boundary and the kerb: electricity, gas, water, telecommunications. To ensure reasonable working space for each utility and to accommodate junction

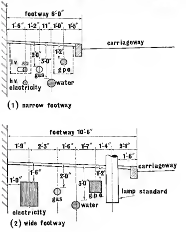


Fig. 7-1 Services under footways

boxes, hydrants, etc. a footway width of 10 ft. 6 in. is suggested, though where there are few pedestrians a lesser width may be accepted provided the mains are moderate in size. Fig. 7–1 shows the suggested disposition of mains in both narrow and wide footways. Electricity and telecommunications mains will require additional cover when placed beneath the carriageway. To accommodate services in narrow footways it may be necessary to site lighting columns at the back of the footway or to fix the lanterns to adjoining buildings.

Where land alongside the road has been acquired for future widening, the undertakers should be allowed to lay their mains on the land in advance of the roadworks, care being taken to ensure that the mains are laid on alignments and at depths in accordance with the final layout. At junctions and other points where services need to cross the road, pipes and ducts for both existing and proposed services should be laid before the roadworks start. Where it is known that additions to services will be needed in the near future it may be advantageous to lay the necessary pipes or ducts along the road in advance of the roadworks. Crossings of existing roads should be made by thrust borings where practicable to avoid disturbing the road surface and the flow of traffic.

In view of the high cost and other disadvantages of subways for the accommodation of services they are unlikely to be constructed along roads, but short subways may be useful where services cross under busy roads or important junctions. Services should usually be carried across road bridges in pipe bays under the footways.

Transmission and trunk mains should preferably be routed along streets of little traffic importance or across open ground. Where, however, they have to be laid along major roads they should be accommodated under the footways, verges or central reserve wherever possible.

To avoid obstruction of the highway any undertakers' equipment located above ground should desirably be sited outside the highway boundary or, if this is impracticable, behind the footway. Although the Postmaster General has special powers to site telegraph poles and other above-ground equipment within the highway it is his normal practice to meet the reasonable wishes of the highway authority on the siting of equipment. Telegraph poles are only erected in urban areas where distribution by underground cable is quite uneconomic.

7.4 Services along or across urban motorways

With the exception of the Postmaster General, statutory undertakers are not entitled to lay apparatus on, under or over land *along* the route of a motorway. Having regard to the paramount need not to restrict or endanger the flow of traffic and in view of the limited space available it will be virtually impossible to accommodate services along motorways additional to those needed for their operation.

Although apparatus may be laid down or erected on lines *crossing* motorways, subject to the consent of the Special Road Authority, including any necessary conditions, the number of such crossings should be as few as possible. Roads crossing over or under motorways will usually serve as convenient crossing points for pipes and cables. On bridges over motorways, pipe bays or cable ducts adequate for future needs should be provided under the footways. Where it is necessary for pipes and cables to cross the motorway at points other than bridges they should be placed at heights or depths suitable for their protection and the safety of the motorway and the traffic thereon; they should normally be placed in sleeves so that they can be withdrawn and replaced from outside the motorway. Manholes, inspection chambers, switch gear, pylons, etc. should be sited outside the boundaries of the motorway so that maintenance and repair work can be carried out without interference to the road or the flow of traffic. Cases where existing apparatus falls within the boundaries of a new motorway should be considered on their merits.

As it may be necessary to provide facilities for telecommunications equipment both along and across motorways the G.P.O. should be consulted at an early stage so that their requirements can be ascertained before bridge and road designs are prepared.

8 Bus and coach services

8.1 Co-ordination of highway and public transport planning

Efficient public transport services must form an integral part of the overall plan for the development of every town and city. The future demand for public transport must be estimated at the forecasting stage of every comprehensive land use/transport study. In all towns public transport should be planned to be as attractive an alternative as possible to the use of the private car, particularly in town centres where some limitation of car usage may be unavoidable (see Planning Bulletin No. 7: *Parking in Town Centres*[22]).

When improving existing roads or planning new ones it is important that there should be full consultation with the Traffic Commissioners and the operators to ensure that suitable facilities are provided for bus and coach services. Consultation should take place in the initial stages of the preparation of road schemes and should cover the provision to be made for bus and coach services to serve existing and proposed development as well as the siting of bus stops, terminals, bus stations and interchange points with other forms of transport.

8.2 Bus routes

Bus routes should be planned to give rapid and convenient access to as many parts of the town as practicable. Roads which are or may be used as bus routes should be suitable in width, alignment and construction and should include bus bays and passenger shelters where necessary. Junctions where buses turn should have easy corner radii and appropriate facilities for turning traffic.

In planning future development early consideration should be given to the likely demand for bus services, so that roads and junctions can be designed accordingly. Failure to foresee such demands may involve the use of unsuitable routes or even the restriction of services.

Buses will normally share roads with other traffic and will be subject to the same controls on movement, but special arrangements may be necessary to ensure that services can be effectively maintained and to avoid delays due to traffic congestion. These may include the application of waiting, loading and unloading restrictions to other vehicles, especially during peak hours, and allowing buses to carry out movements forbidden to other traffic. In some cases the reservation of lanes for use exclusively by buses or the exclusion of traffic other than buses from particular streets may need to be considered.

Buses will mainly be routed along *primary* and *district distributors*, but some routeing along *local distributors* will be needed to give easy access to environmental areas and central pedestrian precincts. Where local services penetrate into environmental areas street and junction layouts must be adequate; streets in environmental areas should not be used for non-stop through services. Buses may be routed along urban motorways but will not be allowed to stop on the through carriageways to pick up or set down passengers. As shown in Fig. 8-1, stops may be located on slip roads at interchanges or on special bus slip roads between interchanges.

8.3 Bus stops

Bus stops should not be sited where their use might unreasonably interfere with the flow of traffic or restrict visibility on bends or at junctions. When considering a site in the vicinity of an intersection its possible effect on traffic movement and the capacity of the approaches and exits should be taken into account.

A bus stop on the approach to an intersection should be far enough away to ensure that:

(i) a waiting bus does not obstruct visibility leftwards from the main road to the side road, or to the right from the side road to the main road;

(ii) traffic wishing to turn left is not obstructed by the bus (if buses turn left at the junction it may be possible to incorporate a bus bay at the beginning of an additional lane for left-turning traffic);

(iii) a bus requiring to turn right after leaving the stop has ample room to cross safely to the lane for right-turning traffic;

(iv) waiting buses do not interfere with the efficient working of traffic signals or the movement of traffic at a roundabout.

To avoid the above difficulties it will often be preferable (provided the road layout and other factors permit) to site bus stops on the exit side of an intersection, especially where bus routes diverge at the intersection.

Stops located midway between junctions have the advantage of avoiding interference with turning traffic, but may sometimes be less convenient for passengers and may tempt them to cross the road at unsuitable points. Where possible, bus stops should be located in conjunction with pedestrian subways and bridges.

Where the width available is insufficient for the construction of a waiting bay and buses have to stop at the normal kerb line, there should be room for at least one line of traffic in the same direction of travel in addition to the space occupied by the bus. To ensure that buses can stop at the kerbside without obstructing the through lanes, other vehicles should not be allowed to park near bus stops.

Bus stops on opposite sides of single two-way carriageways should be staggered, preferably so that buses stop tail-to-tail and move off away from each other. The staggered stops should be 200 to 300 ft. apart.

To maintain reasonable operating speeds and minimise interference to other traffic, bus stops should preferably be spaced at intervals of not less than 1,200 ft. along all-purpose distributor roads. On important roads with a high degree of access restriction a spacing of 1,800 ft. or more may suffice. A lower spacing than normal may be warranted where the demand is heavy, especially where pedestrians might otherwise have to cross a heavily-trafficked junction to reach a bus stop.

Although buses will not be allowed to stop on the through carriageways of urban motorways, stops may be located at bus bays on interchange slip roads and on special bus slip roads at intermediate points with easy pedestrian access to the all-purpose road system. Some typical arrangements are shown in Fig. 8-1.

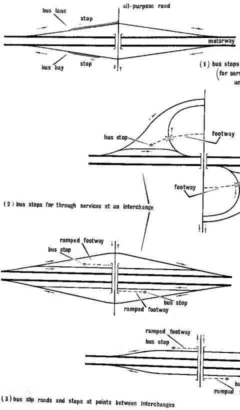


Fig. 8-1 Typical arrangements for bus stops on motorway slip roads

8.4 Bus bays

Where space permits, bus bays should be provided at bus stops. Their length will depend upon the number of buses they may have to accommodate at any one time. As shown in Fig. 4–5 bus bays should preferably be 10 ft. 9 in. wide, but where space is restricted or costs are likely to be high narrower bays will still be useful, the minimum width should normally be 9 ft. At each end, bus bays should be tapered gradually towards the carriageway so that buses can leave or rejoin the traffic stream smoothly and safely. Where bus bays and ordinary lay-bys have to be combined the spaces for buses should be clearly marked so as to permit easy ingress and egress.

To lessen the risk of a bus queue being splashed in wet weather, it is preferable that the crossfall of a bus bay should be outwards from the kerb towards the carriageway. With this arrangement surface-water drainage will require special attention; the provision of slotted drainage blocks across the mouth of the bay may be helpful.

8.5 Passenger shelters

Queue shelters should be erected at busy stops not only to give shelter but to encourage orderly queueing; they should be provided with splash guards to protect the queue from splashing by vehicles. Queue shelters must of necessity be erected adjoining the kerb (with the appropriate clearances as indicated in Table 4–2), and footways may have to be widened to accommodate them. Care should be taken to ensure they do not interfere with sight lines.

Shelters equipped with seats may be desirable where travellers may have to wait for long periods. These should usually be erected at the back of the footway or behind the highway boundary.

8.6 Bus stations and terminals

Where many services radiate from the town centre, bus and coach stations may be required to serve both local and long-distance traffic. There should be full consultation with the operators and with the Traffic Commissioners when such arrangements are being considered. Ideally the stations should be combined or near to one another. If the railway station is close to the town centre it will be convenient if the combined bus and coach station is located nearby.

Bus stations will normally be located within or close to the central area and should have easy access to the distributor road system. Buses should be able to enter and leave the station without delaying or endangering other traffic—preferably without having to cross or turn right against opposing traffic streams. Unless bus stations and their accesses are carefully sited the concentration of bus traffic may overload nearby streets and junctions.

Special attention should be given to the design of pedestrian routes to and from bus, coach and railway stations. Pedestrian crossings, subways and bridges should be provided where necessary. Ideally the stations should be linked to a comprehensive system of pedestrian ways.

Accommodation should be provided off the highway for buses waiting at terminal points during quiet periods; terminals should be designed to avoid any need for reversing, having regard to turning circle requirements. Large factories and offices with special bus services should have space for loading and unloading within their boundaries, with safe access to the highway. Consideration should also be given to the possible need for car parking facilities when picking up passengers at stations or terminals.

The introduction of 'park and ride' facilities from bus stops or terminals on the outskirts of the town or central area is to be considered if the use of cars in the central area is to be discouraged. Provision of all-day car parks adjoining suitable bus stops or terminals and the issue of combined parking and bus tickets will offer the commuter an attractive alternative to the use of the private car for travelling into the town centre.

8.7 Cab ranks

Cab ranks are likely to be required near railway and bus stations. Where possible they should be sited within the curtilage of the stations. Cab ranks at other points should be sited away from main throughfares but should be easily accessible. Cabmen's shelters should be located where they do not restrict visibility or obstruct the footway or carriageway; they should preferably be sited off the highway.

Passenger shelter located behind highway boundary

This bus station is conveniently located directly beneath Birmingham's Bull Ring Shopping Centre

9 Junction design—general considerations

9.1 Accidents at junctions

The need for good junction design is exemplified by the fact that well over half the fatal and serious road accidents in built-up areas occur at junctions.

The value of restricting the number of junctions along major roads has been demonstrated by an analysis of accidents at three-leg priority junctions. This showed that the number of accidents in a given period is approximately proportional to the square root of the product of the flows on the major and minor roads.[21] If two side roads are linked before reaching the major road the number of accidents will be about 30% less than if they join it separately. If several side roads can be combined before reaching the main road the gain will be even greater.

9.2 Junction capacity

The capacity of an urban road is often governed by that of its junctions. If the volume of crossing or turning traffic is small and the major road is lightly trafficked, simple junction designs will suffice, but on busier roads the achievement of the required route capacity and the avoidance of excessive delays will call for the adoption of more complex designs with channelisation, gyratory systems, traffic signals, grade separation, or a combination of these features.

Junctions should normally be designed with sufficient capacity to accommodate the planned future peak flows that are practicable on the network. In planning the network, junction capacity should be kept in balance with that required on the road system between junctions. The impracticability of widening certain roads in the foreseeable future may affect the distribution of traffic and influence junction design. Where road widths are restricted, maximum flows may be estimated by adding 15% to the practical carriageway capacities given in Tables 1–4 and 1–5 and should usually assume prohibition of waiting on the carriageway.

9.3 Design considerations

Junction designs should have regard to the flows, speeds, composition, distribution and future growth of traffic. Where an existing junction is to be improved an examination of the accident record will frequently indicate defects which should be remedied in the new layout. Designs should be tailor-made for each site, with due regard to physical conditions at the site, the amount and cost of the land required, the cost of construction and the effect of the proposals on the neighbourhood. Due allowance should be made for the space needed to accommodate traffic signs, lighting columns, underground services, subways, etc.

The preparation of alternative designs and a comparison of their costs and benefits will often be desirable, especially for the more complex and costly proposals. Where grade separation is envisaged ultimately, any earlier improvements should be planned as far as practicable to conform to the future layout.

9.4 Control of development, access and street parking

Where the improvement of a junction is being carried out in stages over a period of years it is important that development proposals in the vicinity should conform to the ultimate layout. As the efficiency of a junction may be prejudiced by the presence of vehicular and pedestrian accesses, it is essential that all development nearby should be carefully controlled. Places of public resort and other development attracting large numbers of people and vehicles should not be located near a junction unless satisfactory arrangements can be made to avoid interference with the flow of traffic and to ensure the safety of pedestrians.

Where necessary the capacity and safety of junctions should be preserved by prohibiting parking on the approaches and exits and by adopting appropriate measures to safeguard pedestrians.

9.5 Pedestrians at junctions

The difficulty of reconciling the interests of pedestrians with those of other road users is greatest at junctions, since at these points the movements of vehicular traffic are usually complex and demand the close attention of drivers, sometimes to the detriment of pedestrian safety.

When designing junctions the possible need for (and the siting of) guard rails, refuges and pedestrian crossings should be considered. At the busiest junctions pedestrian subways or bridges may be required. At junctions where the construction of special bridges or subways is impracticable or cannot be justified, other methods should be considered; these might include the simplification of traffic movements by channelisation or prohibiting certain turns or, at signal-controlled junctions, the introduction of pedestrian phases.

In planning the future road system provision should be made for the segregation of pedestrian and vehicular traffic at points where there will be heavy concentrations of both and dangerous conflicts will otherwise be likely to occur.

9.6 Visibility at junctions

To ensure safety and maximum capacity it is important that junctions should have at least the standards of visibility recommended in Section 10.2. Where a junction has to be located on a bend, in a cutting, at or near a summit, or near a bridge, the achievement of the required visibility may be difficult, but special care should be taken to comply with the standards. Telephone kiosks, signs, shrubs, etc. should not be placed where they would restrict visibility.

It will assist traffic flow and safety if single-level intersections have reasonably level approaches. The easing of gradients on the approaches may improve visibility and will facilitate stopping and starting, particularly in frosty weather.

9.7 Lighting and signposting

The adequate lighting of junctions in urban areas is essential and should include the illumination of channelising islands and

refuges in a manner sufficient to render them visible even in misty weather. The safety of a junction will also depend on the adequacy of the carriageway markings and traffic signs; these should be provided in accordance with the latest standards and should be maintained in good condition at all times.

9.8 Junction spacing

The spacing between junctions should always have regard to design and traffic requirements such as the lengths needed for right-turn or speed-change lanes or for weaving manoeuvres and should be calculated accordingly. As a rough guide, suggested minimum spacings along various types of road are given below:

Primary distributor (urban motorway)	1,800 ft.
Primary distributor (all-purpose)	900 ft.
District distributor	700 ft.
Local distributor or *access road*	300 ft.

Greater distances should be provided where necessary, as for example between junctions with linked traffic signals, where a spacing of 1,300 ft. would be appropriate between junctions on all-purpose *primary distributors* with a 40 mph speed limit, and one of 900 ft. between junctions on *district distributors* with a 30 mph speed limit.

The location of and spacing between all major points of access, including accesses to bus stations, vehicle parks, etc. as well as junctions, should be carefully considered to ensure safety and freedom from congestion.

10 Priority junctions

At a priority junction, traffic from the minor road is expected to give way to that on the major road and is controlled by a GIVE WAY sign or, at certain minor junctions, by carriageway markings only (where visibility is severely restricted, control may be effected by STOP signs, but these would not be appropriate for new or improved junctions). Priority junctions include three-leg intersections (T, Y or fork) and four-leg intersections (direct or staggered). At these junctions the presence of the major road should always be clearly evident from the layout, signposting and road markings. Where both roads are of about the same traffic importance (e.g. the junction of two *access roads*) priority should be given to one (normally the more heavily trafficked) and the junction designed accordingly.

Many of the design features described in this part will also be applicable to other types of junction.

10.1 Capacity

The curves in Fig. 10–1 are applicable to both T junctions and crossroads. Staggered crossroads should be regarded as two T junctions. For direct crossroads the curves indicate the traffic that can enter from the more heavily trafficked side road.

With good visibility from the side road the capacity of the junction will be as indicated by Curves 1 and 2. When traffic gaps on the major road are long enough, vehicles may be able to emerge from the side road in groups, without necessarily having to stop at the major road.

Curves 3 and 4 show the maximum volume of traffic that can enter or cross the major road from a side road with a single-lane approach when visibility is restricted on the approach but adequate at the stopped position.

These curves afford only a general guide to junction capacity in urban conditions. Gaps in the major road flow caused by traffic signals or pedestrian crossings nearby may increase capacity. On the other hand, capacity may be reduced by unequal directional distribution of traffic on the major road, substandard visibility at the junction, an up-grade on the side road approach, or a high proportion of heavy traffic from the side road.

Improved capacity can be obtained where the major road has a central reserve wide enough to shelter traffic and permit movements to or from the side road to be made in two parts. A reserve width of at least 15 ft. is desirable for this purpose.

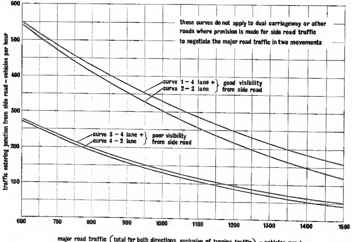


Fig. 10–1 Capacity of priority junctions

10.2 Visibility

At priority junctions full visibility will be needed to the right and left between points 3 ft. 6 in. above road level over areas defined by:

(i) a line x ft. long measured along the centre line of the side road from the continuation of the nearer edge of the major road carriageway (for values of x see Table 10–1);

(ii) a line y ft. long measured along the nearer edge of the major road carriageway from its intersection with the centre line of the side road (for values of y see Table 10–1);

(iii) a straight line joining the ends of the above lines.

Table 10–1 Visibility distances at priority junctions

Type of major road	Speed limit mph	Minimum visibility distance y ft.
All-purpose *primary distributor*	50 40	500 400
District or *local distributor*	30	300
Access road	30	200

The x distance should normally be 30 ft. Some reduction may be reasonable if the side road is lightly trafficked, as may be so for some culs-de-sac and other *access roads*. On such roads the x distance may be reduced to 15 ft. in urban areas, but the y distance should remain the same.

These standards will apply to new junctions and, where possible, to improved junctions. It is recognised, however, that site difficulties may sometimes make it impossible to improve existing junctions to the standards recommended above. In such cases the best possible sight lines should be provided, but full visibility y should always be obtainable from a point on the centre line of the side road either in line with the continuation of highway boundary of the major road or 7 ft. back from the edge of the major road, whichever gives the greater x distance.

If the major road is one-way a single splay line in the direction of approaching traffic will suffice. Similarly, if the major road has dual carriageways with no gap in the central reserve only a single splay line to the right will be needed. If the side road serves as a one-way exit from the major road, no splay will be required provided forward visibility for turning vehicles is adequate (Table 13–3 gives appropriate stopping distances for various radii).

Where the major road has dual carriageways with a central reserve wide enough to shelter turning vehicles (15 ft. or more) the normal visibility splay to the left of the side road will not be needed, but the central reserve should be clear of obstructions to driver visibility for at least y ft.

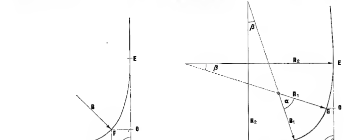
Dangerous conditions may arise if, despite the provision of visibility splays, vehicles are allowed to park within the splay lines, thereby obstructing visibility. Where necessary, parking and access should be controlled to minimize this risk.

10.3 Corner radii

Junctions should be designed so that vehicles do not have to go over to full lock when turning. In view of the relatively small proportion of vehicles with turning circles in excess of 70 ft. diameter, a kerb radius of 35 ft. will suffice for junctions used by commercial vehicles. In residential streets a kerb radius of 20 ft. should normally be regarded as the minimum.

Turning can be made easier and safer by providing transition or compound curves on the corners instead of circular arcs. This will reduce risks due to vehicles swinging out of lane to avoid the rear wheels hitting the kerb. The transition or compound curves should have a minimum radius appropriate to the type of traffic using the junction. Compound curves will normally be three-centred, but two-centred designs will sometimes be useful. The major radius or radii should be two or three times the minor radius; the arc lengths of each segment should be about the same.

The use of spirals and compound curves in junction design is illustrated in Fig. 10–2.



min.radius B	AC.CE	AB.OE	BF.OF
35′	65·4′	51·6′	13·8′
30′	56·0′	44·2′	11·8′
20′	37·4′	29·5′	7·8′

(1) spiral

R_1	R_2	β	α	AC.CE	AB.OE	BF.OG
35′	105′	18°	54°	60·5′	32·9′	5·1′
30′	90′	18°	54°	51·8′	20·2′	4·4′
20′	60′	19°	54°	34·5′	18·9′	2·9′

(2) compound curve

Fig. 10–2 Corner design

10.4 Channelising islands

Channelising islands should be provided where necessary at priority and other types of junctions:

(i) to separate conflicting traffic streams;
(ii) to assist traffic streams to intersect or merge at suitable angles;
(iii) to control vehicle speeds;
(iv) to provide shelter for vehicles waiting to carry out certain manoeuvres such as turning right;
(v) to encourage drivers to take the correct path and deter them from taking incorrect ones;
(vi) to assist pedestrians to cross;
(vii) to reduce excessive carriageway areas.

Fully channelised designs may require too much space for universal adoption, but it will often be useful both to safeguard and to facilitate major turning movements by partial channelisation. Separation of the less important turning movements may not be necessary or may be impracticable without making the channelising islands too small.

To enable islands to be seen clearly they should usually be bordered by raised kerbs and should have an area of at least 50 sq. ft.; smaller areas may be defined by carriageway markings alone. Risk of overriding the islands can be reduced by slightly offsetting the approach nose from the edge of the carriageway, as shown in Diagrams (1) and (2) of Fig. 10–3; an offset distance of 1 or 2 ft. will usually be suitable in urban areas. Where necessary, additional guidance to traffic should be given by carriageway markings in advance of the nose [Diagram (3)]. The markings should be reinforced by diagonal white stripes or chevrons where it is particularly important that the nose should be conspicuous [Diagrams (4), (5) and (6)].

It is important that channelised junctions should be well lighted at night. Without adequate lighting they may be confusing to motorists.

10.5 Refuge islands

A traffic refuge can serve as both a channelising island and a haven for pedestrians. A refuge on the minor road at a T junction should preferably be sited so that the end nearer the intersection is at least 10 ft. behind the continuation of the kerb line of the major road. There should be sufficient room on both sides of the refuge to enable large vehicles to turn comfortably into and out of the side road. Where the major road has four or more lanes the clearance for traffic turning into the side road should preferably be 18 ft. and not less than 15 ft., that for traffic emerging from the side road should be at least 12 ft. These clearances should be measured to the continuation of the main kerb lines of the side road, not to the radius kerbing on the corner (see Diagram (2) of Fig. 10–6). If the major road has only two lanes even greater clearances will be needed where large vehicles turn, and it may be impracticable to site a refuge on the minor road sufficiently near the junction to be useful to pedestrians.

Refuges should only be provided on the major road at a junction if it is at least four lanes wide. Where possible, the normal lane width of the major road should be maintained past the refuges, but if some reduction is unavoidable the clearances should not be less than 18 ft. The refuges should be sited as near to the junction as possible but should allow ample room for large vehicles to turn into and out of the side road. Refuges may be located in the manner suggested in Section 10.7 for positioning gaps in a central reserve; it will often be useful to site them temporarily in the first place in order that the position best suited for local conditions can be determined by observation.

The carriageway widths of both major and minor roads should be increased as necessary to accommodate traffic refuges. The additional width should be obtained by the gradual widening of the approaches, preferably on flares not sharper than 1 in 25.

Typical junction designs incorporating refuges are shown in Figs. 10–6 and 10–7. Recommendations on the construction and illumination of refuges are given in Sub-Section 4.1.8.

10.6 Carriageways in junctions

Where any length of a single-lane or two-lane carriageway in a channelised or grade-separated junction is on a sharp bend it should be made wide enough to ensure adequate clearances, with due allowance for vehicle widths, frontal overhang and off-tracking of the rear wheels. Suggested carriageway widths for turnings used by large commercial vehicles are given in Table 10–2 (for lane widening on larger curves see Sub-Section 4.1.2). The widths in the second column are appropriate for short turnings at channelised junctions and single-lane carriageways of one-way slip roads (see Section 13.3); those in the third column are suitable for longer connections and also indicate desirable carriageway plus nearside verge widths for single-lane one-way slip roads, those in the last column apply to either two-way or one-way carriageways requiring two traffic lanes. Compound curves or curves with transitional approaches should be used where possible on sharp bends.

Table 10–2 Carriageways in junctions

Inner radius ft.	Single-lane width ft.	Single-lane width with space to pass stationary vehicle ft.	Two-lane width for one-way or two-way traffic ft.
35	18	34	38
50	17	31	35
75	16	28	32
100	15	26	30
125	14	25	29
150	14	24	28
200	14	23	27

10.7 Gaps in the central reserve

To ensure that large vehicles can turn right without difficulty to or from the major road, the gap in the central reserve at a junction should normally extend at least 10 ft. beyond the continuation of both kerb lines of the minor road to the edge of the major road (see Fig 10–4) and should also be determined by 40 to 50 ft. radius control circles tangential both to the centre line of the minor road (or to the sides of any refuge or island) and the side of the central reserve away from the minor road. To facilitate turning the ends of the central reserve should be bullet-nosed.

10.8 Speed-change lanes

Provision of full-length acceleration and deceleration lanes will rarely be warranted at priority junctions in urban areas, but the provision of shorter lanes to assist merging and diverging manoeuvres may be useful in conjunction with channelised designs. Lane lengths will depend on site conditions but should desirably be at least half those quoted in Table 13–2.

10.9 Right-turn lanes

Storage lanes for right-turning traffic constructed within the width of the central reserve are useful both on new schemes and

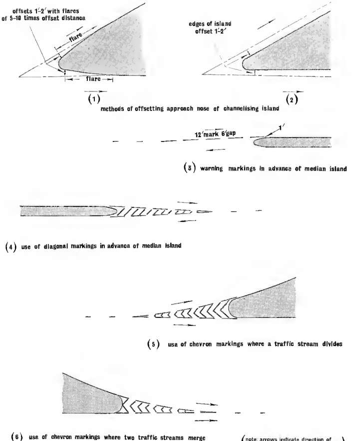


Fig. 10-3 Channelising islands

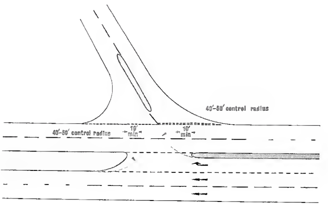


Fig. 10–4 Gap in central reserve at junction

as modifications of existing layouts. These lanes should normally be designed as full-width deceleration lanes with an end taper of 100 ft. Suggested lengths for right-turn lanes (including the end taper) are shown in Table 10–3. The overall length should be increased as necessary if more than one or two vehicles are likely to be waiting to make the turn at any one time. Where space is restricted shorter lanes will still be useful; in these circumstances the length of the end taper should be reduced before that of the full-width lane.

Table 10–3 Length of right-turn lanes

Design speed of major road (mph)	50	40	30
Length of right-turn lane, including 100 ft. end taper (ft.)	400	330	260

10.10 Reducing the number of conflict points

Methods of improving safety by separating traffic streams and points of conflict have been outlined in Section 10.4. Methods of improving safety by reducing the number of points of conflict arising from right-turning movements are equally important and can make a material contribution to the capacity of an intersection.

Examples of traffic cuts at the junction of roads with two traffic lanes are shown in Fig. 10–5. As shown in Diagram (1) there are normally three traffic cuts at a T junction. Prohibition of the right turn from one leg (2) or the introduction of two-phase signal control (3) will reduce the number of cuts to one. If the head of the T is one-way there will either be no cuts or one cut, depending on the direction of the one-way stream (4). If the tail is one-way there will be one cut (5), but this can be eliminated by prohibiting the right turn (6).

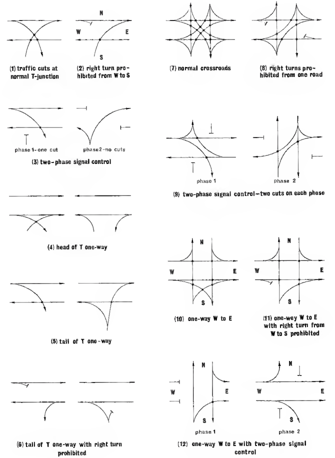


Fig 10-5 Traffic cuts at T junctions and crossroads

At a crossroads there are normally sixteen traffic cuts (7); the number can be reduced to eight by prohibiting right turns from one road (8) or to four by the introduction of two-phase signal control (9). If one of the roads is one-way the number of conflict points is reduced to seven (10), or to five if right turns are banned from one road (11), or one if two-phase signal control is introduced (12).

10.11 Typical designs for three-leg junctions

Some typical designs for three-leg junctions are shown in Fig. 10–6 and are described below. These designs should be adapted as necessary to meet the physical and traffic requirements of any particular site. Similarly the carriageway markings should be chosen with regard to site conditions; those shown in this and subsequent figures are given as examples only.

Diagram (1) shows a conventional layout with the head of the T at or nearly at right angles to the stem. The aim should be to provide corner radii of 35 ft. where the side road is used by a considerable volume of commercial traffic and radii of at least 20 ft. at junctions used mainly by private cars. As indicated in Section 10.3 the use of transition or compound curves on the corners will facilitate turning movements and lessen interference to other traffic. Visibility splays should be as recommended in Section 10.2.

The widening of the side road to accommodate a refuge or channelising island is illustrated in Diagram (2). The refuge should be sited far enough back from the carriageway of the major road to avoid any obstruction to turning traffic, but should not be so far back that it would not be used by pedestrians. A set-back of 10 ft. to the tip of the refuge will enable a car turning into the minor road to stop clear of the major carriageway when pedestrians are crossing the mouth of the junction. A right-turn lane is provided on the major road to the east of the junction (assuming north to be at the top of the page). The major road has been widened on the north side and allows east-west traffic a straight run without risk of encroaching on the right-turn lane. Lane and arrow markings will be required to indicate clearly the paths to be followed by through and turning traffic.

Where the major road has four lanes (possibly divided by a chain of refuges) but cannot be widened to include a right-turn lane, the layout in Diagram (3) may be suitable provided the proportion of traffic turning right from the major road is not high enough to obstruct through traffic. But, where space permits, layouts incorporating a separate right-turn lane are much to be preferred. Also shown in (3) is the provision of a second approach lane on the side road to increase the capacity of the junction.

Although the orthogonal layouts described above will be typical of most urban T junctions, right-hand splay layouts as shown in Diagram (4) are acceptable provided the major road has a single carriageway and the angle between the roads is not unduly acute—an angle of 60° should be regarded as the normal minimum. This layout eases major-to-minor right turns and minor-to-major left turns, but makes it more difficult for vehicles turning around the acute angle. Where the major road has dual carriageways the side road should be preferably realigned as in Diagram (5) to enable the crossing of the nearside carriageway of the major road to be made as nearly as possible at right angles. The central island in the side road should extend around the bend. Where possible the central reserve of the major road should be wide enough to accommodate a right-turn lane; a reserve width of at least 15 ft. is desirable for this purpose. Local widening of a narrow reserve to provide a right-turn lane is shown in Diagram (6), which also includes a fully channelised layout for the mouth of the junction.

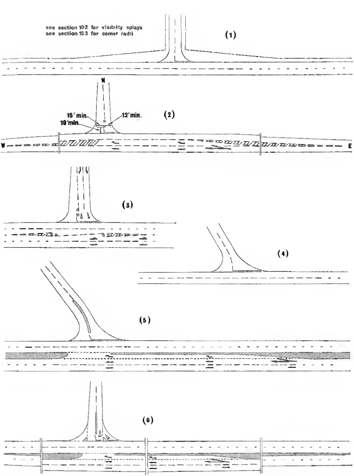


Fig. 10–6 Three-leg junctions

Where the side road has an appreciable left-hand splay as shown by dashed lines in Diagram (7), it is difficult to turn right to or from the major road. Designs with an appreciable splay are undesirable unless it is intended to prohibit right turns. The simplest method of improving a junction of this type is to ease the splay by introducing a gradual bend on the side road, as shown in the diagram. Where there is a heavy left turn into the side road it may be preferable to form a one-way connecting road by means of a single channelising island, as shown in Diagram (8). At more important junctions a greater measure of channelisation may be required as in Diagrams (5) and (6).

Where a side road on a left-hand splay is linked to another side road as in Diagram (9) the undesirable movements to and from the splay road can be suppressed by making it one-way as shown and prohibiting the right turn from the major road. If there is a heavy right-turn movement from west to south at the crossroads it will sometimes be useful to divert the right-turning stream via the splay road, thereby replacing the turn by a direct crossing from north to south as indicated in the diagram.

The right-hand and left-hand splay layouts described above can usually be adapted to suit Y junctions. Where, however, traffic volumes on both branches of the Y are approximately equal the channelised layout shown in Diagram (10) may be more appropriate. The layout does not allow turning movements from A to B, but provision can be made for these where necessary by means of a link road as shown in the diagram.

Diagrams (1) to (8) provide for all turning movements at the junctions. As indicated in Section 10.10 junctions can be made safer by reducing the number of right turns; this reduction will usually enable the design to be simplified. In Diagram (11) the side roads are one-way and all right turns are prohibited; there are no gaps in the central reserve opposite the junctions. If the side road is two-way and heavily trafficked it may be desirable to extend the channelising island into the major road as in Diagram (12); the through lanes and turning lanes should be clearly indicated by arrows on the major road approach.

10.12 Typical designs for four-leg junctions

Where two important roads cross, control by traffic signals, a roundabout or grade separation is desirable, a direct crossing will then be more appropriate than a staggered layout. Where, however, the minor road is lightly trafficked and there are enough gaps in the traffic streams on the major road the staggered layouts shown in Fig. 10–7 may be suitable for junction improvements. When designing new networks it should normally be possible to avoid the need for staggered layouts.

The design of a staggered crossroads will be similar to that of two T junctions. The priority of the major road should be clearly evident from the junction layout, carriageway markings and signposting. Standards of visibility should be as specified in Section 10.2.

In Fig. 10–7 alternative designs are shown for right-left staggers and left-right staggers; the former are preferable from the safety aspect and should be used where circumstances permit.

Diagrams (1) and (2) show simple layouts suitable for lightly-trafficked major and minor roads where the volume of cross or right-turning traffic is small enough not to create any difficulties.

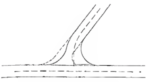
Diagrams (3) and (4) will be suitable for greater volumes of turning and cross-traffic. In both designs the major road has been widened to provide an additional lane for right-turning traffic. Layout (4) has the disadvantage that the length of the right-turn lanes is limited by the distance between the side roads.

Where the major road has a four-lane carriageway divided by a chain of refuges or a narrow central reserve the layouts (5) and (6) may be appropriate if the width available is limited and the volume of right-turning or crossing traffic is low. But layouts (7) and (8), which include right-turn lanes, are much to be preferred where space permits. The bambone-shaped dividing island provided in (8) will require an overall central reserve width of at least 20 ft. and does not provide storage lanes long enough for deceleration clear of the through traffic streams. Full channelisation of the junction mouths will only be required at the more important junctions.

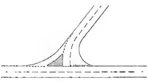
10.13 Multi-leg junctions

Multi-leg junctions (as shown in Diagram (1) of Fig. 10–8) are liable to be confusing and dangerous, and, where possible, side roads should be joined before reaching the junction so that a simplified layout can be achieved (2). Alternatively a roundabout layout may be suitable provided adequate weaving lengths can be obtained (3). A roundabout layout with grade separation for the major route is shown in (4).

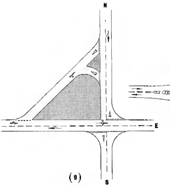
Traffic movements at complex junctions can frequently be simplified without altering the layout by the introduction of one-way working on one or more legs of the intersection.



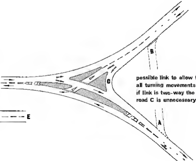
(7)



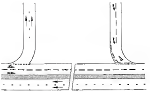
(8)



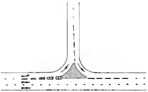
(9)



(10)



(11)



(12)

the following symbols indicate traffic movements but are not carriageway markings :-
permitted movements thus —►
prohibited movements thus —|

Fig. 10-6 Three-leg junctions (*continued*)

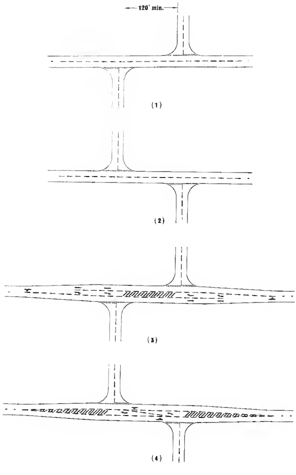


Fig. 10–7 Four-leg junctions

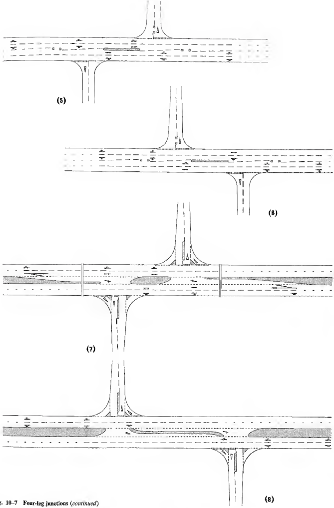


Fig. 10–7 Four-leg junctions (*continued*)

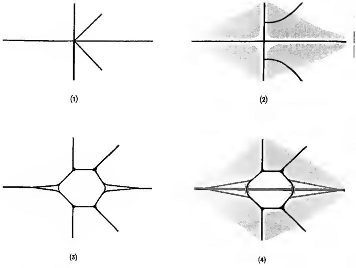


Fig. 10–8 Multi-leg junctions

11 Signal-controlled junctions

When priority junctions in urban areas become overloaded, congestion and accidents will result. Improved safety and often additional capacity can be obtained by the installation of traffic signals, though at times when flows are light delays may be greater than with priority control. Signals can often be installed without need for additional land or major changes of layout.

For further information on the design and capacity of signal-controlled junctions reference should be made to *Urban Traffic Engineering Techniques*,[7] *Road Research Technical Paper No. 56*[22] and *Road Note No. 34*.[23]

11.1 Types of signals

In Great Britain most traffic signals are vehicle-actuated and the green periods are related to traffic demands. The standard sequence is: red—red/amber shown together—green—amber. The amber period is standardized at three seconds and the red/amber at two seconds; the two-second red/amber is provided only by the latest controllers, the older type giving a three-second red/amber.

The latest types of vehicle-actuated signals include the following facilities:

(i) *Minimum green period.* This is the shortest period of right of way which is given to any phase and is long enough for vehicles waiting between the detector and the stop line to get into motion and clear the stop line. The period is variable and depends on the number of vehicles waiting at the start of the green period.
(ii) *Vehicle-extension period.* The minimum green period may be extended by vehicles which cross the detector during the green period. Each vehicle, as it crosses the detector, extends the green period by an amount called the vehicle-extension period. The extension depends on the speed of each vehicle, as measured at the detector, and is automatically varied to enable the vehicle to reach 10 or 20 ft. beyond the stop line.
(iii) *Maximum period.* To limit delay on the waiting phases when there is a continuous stream of traffic on the running phase a maximum period is timed off, after which the signals change right of way independently of any outstanding vehicle-extension period. The maximum period is timed from the beginning of the green period if vehicles are waiting on other approaches or from the moment the first vehicle passes over the detector on one of the other approaches. When required the maximum period can be made variable so that the normal maximum can be extended if at the expiration of the period the traffic flow is above a pre-set value.
(iv) *Intergreen period.* The standard intergreen period is 4 seconds (3 seconds on old equipment), but when a longer clearance is necessary for safety, e.g. to protect clearing traffic, a variable clearance period can be provided. Additional clearance is then given whilst vehicles are clearing the junction, but is omitted if there is no traffic clearing (for special conditions a fixed extra clearance can be given).
(v) *Early cut-off.* To facilitate a heavy right-turn movement from one approach the green time of the opposing stream can be cut off a few seconds early. The duration of the early cut-off period can readily be adjusted by detectors operated by the turning traffic.
(vi) *Late start.* An alternative way of facilitating a heavy right turn is to delay the movement of the opposing traffic stream for some seconds.

11.2 Co-ordinated control systems

Owing to the frequency of junctions in urban areas the linking of signals is often desirable to reduce delays to traffic. One object of co-ordination is to establish a definite relationship between the appearance of the green period at two or more intersections so that interference to the through traffic streams is reduced to a minimum. When two intersections are very close to each other some form of linking is often used to prevent the queue of vehicles at one intersection from extending back and interfering with the other. The interlocking arrangements can be made very flexible if vehicle-actuated signals are used.

Brief details of some methods of linking signal installations are given below:

(i) *Simultaneous system.* All signals along the controlled section display the same aspect to the same traffic stream at the same time. This system has the disadvantage that it may encourage speeding, as drivers may try to get through as many intersections as possible before the signals change.
(ii) *Alternate (or limited progressive) system.* With this system adjacent signals show opposite indications alternately along the route. The aim is that vehicles should travel one block in half the cycle time. If drivers exceed the design speed of the system they are stopped at each signal. The system is not very suitable for streets where the distance between junctions varies appreciably.
(iii) *Flexible progressive system.* The cycle time for all intersections in the system is the same, but the green periods are displaced with respect to each other according to the desired road speed. This is intended to give a progression of green periods along the road—in both directions if the road is two-way. If desired this system can be adapted to give preference to certain directions, e.g. preference can be given during the morning peak to traffic flowing towards the town centre and during the evening peak to traffic flowing away from the centre. The cycle time for the system can be made to vary according to the traffic requirements.
(iv) *Tailor-made systems.* Systems of linked signals are often tailor-made for particular routes. These systems do not generally have a master controller as this may lead to less efficient control at key intersections along the route. These key intersections are usually allowed to operate in a fully vehicle-actuated manner and to govern changes of right of way at neighbouring intersections.
(v) *Area Traffic Control.* A new development is the use of digital computers to provide a system of area traffic control. The purpose of such control is to reduce delays by:

(a) more efficient linking of signals, having regard to the traffic situation at any given time;

(b) diversion of traffic where spare capacity is available on alternative routes;

(c) lane switching, or switching of peak period one-way systems, on tidal flow routes

Evaluation of the benefits of area traffic control systems is at present in hand.

11.3 Pedestrian signals

Pedestrians at intersections controlled by signals are catered for in two ways in Great Britain. One method is to provide a crossing marked out in studs in front of the stop line (see Fig. 11-4) whereby pedestrians crossing the road fit in with the signal timings, i.e. no special phases are given for them. This type of crossing is normally used where there are not too many turning vehicles. The second method is to provide a special phase for the pedestrians and in this case the pedestrians' movements are signalled. This is a more positive method as all traffic which may pass over the crossing is halted before the pedestrian phase is given, but causes more delay to vehicles.

Existing pedestrian signals display the word WAIT in red and the word CROSS in white or green, all against a black background. As recommended in *Traffic Signs 1963*[11] future signals will show either a red standing man or a green walking man, both against a black background.

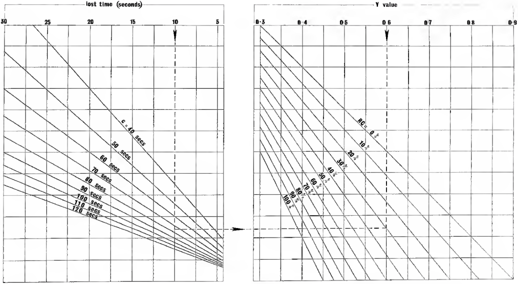
The pedestrian phase may be brought in either by operation of a push button (this is the normal arrangement and avoids unnecessary delay to vehicles) or automatically (this may be desirable on linked signal systems to avoid signals with pedestrian phases getting seriously out of step with adjacent signals). The green signal to pedestrians is displayed for a pre-set period of 6 to 10 seconds according to the pedestrian flow. It is usually preceded by an all-red period of about 2 seconds and followed by an all-red period of 2 to 8 seconds, depending on the width of the road.

Pedestrian crossings between junctions can be signalled in the same way. With one type of pedestrian-operated signal no vehicle detectors are installed and the right of way normally rests with the traffic. In the absence of demands from pedestrians it would remain so indefinitely, but when the push button is depressed the pedestrian receives right of way immediately (provided a pre-set minimum right-of-way period for vehicular traffic has expired since the pedestrian phase was last called). It is often possible to omit vehicle detectors without difficulties arising, but where vehicle approach speeds are high it is usually advantageous to provide them.

One difficulty with the pedestrian signals described above is that the pedestrian phase and clearance periods, being of fixed duration, have to be set to meet average conditions. This results in unnecessary delays to vehicles when only a few pedestrians wish to cross and to inadequate time for pedestrians at peak pedestrian times. Experiments are therefore in hand with a view to introducing a more flexible type of pedestrian crossing where the signal sequence to vehicles includes a flashing amber period following the red signal; during this period vehicles must give way to any pedestrians wishing to cross but may move over the crossing in the absence of pedestrians. Detectors would be required only where vehicle approach speeds were high.

11.4 Filter signals

Filter signals mounted alongside the main signals are sometimes used to permit movement of vehicles in the direction shown by the green arrow, even though the main signal is showing red. Filtering creates problems for pedestrians, particularly for those



To calculate reserve capacity, use the left-hand diagram to obtain a point corresponding to the lost time and the maximum cycle time suitable for the junction, extend a line horizontally from this point to the right-hand diagram to meet a vertical line corresponding to the Y value—the reserve capacity (RC) may then be read at the point of intersection.

Example shown:
Lost time = 10 seconds Cycle time = 75 seconds
Y value = 0·6 *Reserve capacity* = 30 %.

Fig. 11–1 Traffic signal calculations: reserve capacity diagram

crossing the road from which the vehicle emerges. It also involves risk of collision with vehicles in any traffic stream with which the turning vehicle merges. For those reasons filter movements should be restricted to sites where a substantial advantage in handling traffic can be achieved and pedestrian needs can satisfactorily be met despite these movements. Special precautions may have to be taken depending on the site conditions, e.g. by erecting guard rails to prevent pedestrians crossing the approach with the filter movement or by siting the stop line 20 to 30 ft. from the pedestrian crossing to enable drivers and pedestrians to see each other.

A left-turn connecting road may sometimes be provided as an alternative to a left filter and will allow traffic to turn left before reaching the signals. An example of this layout is shown in Diagram (9) of Fig. 10–6.

A green arrow is sometimes shown with a full green to indicate to drivers that they can turn right safely as an early cut-off has been imposed on the opposing traffic stream.

11.5 Capacity

For additional information on the capacity of signal-controlled junctions, References 7, 22 and 23 should be consulted.

11.5.1 Phasing

To achieve high capacity and reduce delay, as much traffic as possible should be kept moving at the same time and main traffic streams which do not conflict should be arranged to run at the same time. The number of phases will depend on the number of roads entering the junction and the amount of right-turning traffic.

Two-phase control should be adopted where possible, but additional phases may be needed:

(i) where troublesome conflicting movements cannot be eliminated;
(ii) where right turns are too heavy to be dealt with by early cut-off or late start features or by extending the intergreen period;
(iii) at complex junctions with five or more legs;
(iv) at junctions where separate pedestrian phases are required.

Before adopting multi-phase control the alternative of altering traffic movements so as to permit two-phase control should always be considered.

Vehicle-actuated signals are usually arranged so that if no demand is received for a particular phase it can be omitted from the cycle, thereby reducing delays.

11.5.2 Reserve capacity

The reserve capacity (*RC*) of a junction at a given date is the difference between its practical capacity and the actual or estimated flow at that date, expressed as a percentage of the actual or estimated flow. To avoid excessive delays the flows used to determine the practical capacity of signal-controlled junctions are taken as 90% of the maximum possible flows.

Reserve capacity may be estimated from the nomogram in Fig. 11–1. The terms used in the nomogram are described below:

(i) *Lost time* (*L*). This is the total period during the cycle which is not effectively used for vehicle movement. It is made up of the time when all signals show red or red/amber plus an allowance of 2 seconds per change of phase to allow for tailing-off of flow during the amber period and starting delays at the beginning of the green period. At each change of phase the lost time amounts to 1 second less than the intergreen period.

Examples of signal aspects for two-phase control are illustrated in Fig. 11–2. Diagram (1) shows the normal 4-seconds intergreen period with 3 seconds lost time (made up of 1 second when all signals are either showing red or red/amber plus the 2-seconds allowance for tailing-off of flow and starting delays). As there are two changes of flow per cycle the total lost time per cycle (*L*) is 6 seconds.

Diagram (2) shows an intergreen period of 12 seconds, as may be needed to enable pedestrians to cross the road or vehicles to turn right or clear a wide intersection. This allows an all-red period of 7 seconds and has 11 seconds lost time. If the lost time at the second change of phase is 3 seconds the total lost time per cycle will be 14 seconds.

(ii) *Cycle time* (*c*). If right-turning traffic does not create difficulties the capacity of an intersection becomes greater as the cycle time increases because the ratio of lost time to useful time decreases. As, however, the gain in capacity with very long cycles is often insignificant it is usual to limit cycle times to 120 seconds. Cycle times should not be so long that queues of waiting vehicles extend beyond the available reservoir space or right-turning vehicles cause congestion by interlocking or by unduly interfering with through traffic movements. Linked signals generally require short cycles to ensure reasonable progression. Long cycles may be needed when lost time is high (as with multi-phase control) and on commuter and holiday routes (to ensure saturation of side road green periods).

(iii) *Sum of flow ratios* (*Y*). The ratio of the actual hourly flow to the saturation flow per hour of green time should be determined for each phase and totalled for all phases. The saturation flow is that which would be obtained with 100% green time and a continuous queue of vehicles on the approach; it is expressed in passenger car units, using the weightings given in the fifth column of Table 1–3.

As any phase may include flows from more than one approach the highest approach ratio should be chosen to represent the phase.

The saturation flow on each approach will depend mainly on its width and to a lesser extent on the amount of turning traffic, the composition of traffic, the gradient, the presence of parked vehicles and the nature of the site. With no turning traffic and no parked vehicles the peak period saturation flows for approach widths of between 10 and 17 ft. are as follows:

Table 11–1 Saturation flows

Approach width (ft.)	10	11	12	13	14	15	16	17
Saturation flow (pcu's per hour)	1850	1875	1900	1950	2075	2250	2475	2700

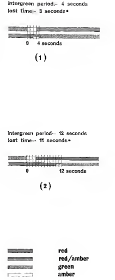
For greater approach widths (at least up to 60 ft.—the limit of present experimental observations) the saturation flow may be calculated from the expression

$$s = 160\ w$$

where s is the saturation flow in pcu's per hour and w the effective approach width in ft. (see References 22 and 23).

The above figures allow for the effect of left-turning vehicles on the saturation flow. Right-turning vehicles, except when they have an unopposed movement, should be allowed for as follows:

(a) If they are so few that a separate right-turn lane is unnecessary the effect of each right-turning vehicle on its stream may be taken as equivalent to $1\frac{3}{4}$ straight-ahead vehicles.



* lost time at each change of right of way is assumed to be 2 seconds plus the time when either red or red/amber signals show to both phases

Fig. 11–2 Examples of signal aspects at 2-phase traffic signals

(b) If no right-turn lane is provided and vehicles waiting to turn are sufficiently numerous to obstruct the straight-ahead flow, the saturation flow of the remaining vehicles may be estimated from the reduced approach width; a reduction of 7 ft. may suffice for a turning stream of cars and light vans but one of 9 ft. may be needed where there is a high proportion of heavy vehicles (say over 20%).

(c) Where a right-turn lane is provided the saturation flow will relate to the remaining approach width and the flow of straight-through and left-turning traffic.

The above results apply to an average intersection. If conditions are exceptionally good (e.g. on dual carriageways with good visibility and alignment, adequate turning radii and exit widths, and no interference from pedestrians) the saturation flow should be increased by 20%. If conditions are poor (e.g. with poor visibility and alignment, and with considerable interference from pedestrians) the saturation flow should be reduced by 15%.

To allow for gradients on the approaches the saturation flow should be reduced by 3% for every 1% of uphill gradient and increased by 3% for every 1% of downhill gradient. This applies to gradients of between 10% uphill and 5% downhill.

Parked vehicles in the vicinity of an intersection may seriously affect its capacity and efficient operation. The effect of a parked vehicle on an approach may be expressed as follows:

$$\text{Effective loss of carriageway width (ft.)} = 5.5 - \frac{0.9\,(z - 25)}{g}$$

where z is the clear distance in ft. of the nearest standing vehicle from the stop line and g is the green time for the approach in seconds. If z is less than 25 ft. it should be taken as 25 ft. If the expression is negative the effective loss in all cases will be zero. The effective loss should be increased by 50% for a bus, lorry or wide van.

11.6 Design

Signal installations should be designed to meet peak conditions with appropriate reserve capacity. Information will be required on traffic volumes and turning movements for each peak period and on the estimated rate of growth. Traffic diagrams should then be examined in conjunction with a large-scale plan of the junction to enable the most suitable signal phasing and site layout to be determined. For high capacity and minimum delay, main traffic streams which do not conflict should be phased to run at the same time. Layouts should be compact so that clearance times between phases are kept as short as possible. Layout and phasing proposals may have to be adjusted to ensure adequate reserve capacity.

The sections in Chapter 10 dealing with kerb radii, channelising islands, refuges, gaps in the central reserve at junctions, right-turn lanes and methods of reducing traffic cuts are also applicable to the design of signal-controlled junctions.

The designs for three-leg junctions illustrated in Fig. 10–6 are all suitable for signal control. The arrangement shown in Diagram (9) of the figure for converting a right turn at a cross-roads into direct crossing will often be useful and will enable heavy right turns to be dealt with by simple two-phase control. The channelised Y junction illustrated in Diagram (10) will only require two-phase signal control at the central intersection.

For signal-controlled four-leg junctions the staggered layouts shown in Fig. 10–7 will not normally be appropriate. Unless there are special site difficulties, layouts with direct crossings will be more efficient.

Signal control can often be applied to multi-leg junctions without need for major alterations to the layout, but may require three

or more phases. To develop maximum capacity two-phase operation is desirable, and may sometimes warrant modification of the junction layout, possibly with the prohibition of less-important traffic movements. If multi-phase operation is unavoidable it may be necessary to widen the approaches substantially to obtain the required capacity.

11.6.1 Visibility

Standards of visibility at signal-controlled junctions need not be so high as at priority junctions, but provision of reasonable inter-visibility between the various legs of a junction will give drivers confidence and promote safety and smooth traffic flow. Visibility should be good enough to enable drivers approaching the stop line to see as far as the stop lines on the other approaches and preferably 20 ft. or so beyond.

It will usually suffice to set back boundary fences or buildings on each corner behind a splay line joining points on the kerbs 40 to 50 ft. back from the intersection of the kerb lines at the corner. The precise set-back of the splay line will depend on the kerb radius and the footway width required around the corner.

11.6.2 Selecting approach widths

Because signal control permits traffic movement from any approach for only a proportion of the time it is sometimes necessary for the intersection approaches (where queueing takes place) to be wider than the roads which feed these approaches, in order to pass the required flows.

A preliminary assessment of the minimum approach widths needed for new or improved four-leg junctions with two-phase control may be made by means of the formula:

$$\frac{w_1}{w_2} = \frac{g_1}{g_2} = \sqrt{\frac{q_1}{q_2}}$$

where q_1 and q_2 are the larger approach flows in pcu's during Phases 1 and 2 respectively;
g_1 and g_2 are the green times;
w_1 and w_2 are the corresponding approach widths.

Thus a major approach carrying four times as much traffic as a minor approach should be twice as wide and have twice as much green time. The lengths of the widened parts of the approach should theoretically bear the same ratio. In some cases this rule may give approach widths for the major road which are less than those of the feeder roads. For obvious reasons these approaches should not be narrowed but should retain a constant width. Thus, in these cases more width is provided than is strictly necessary according to the above rule. In consequence, the green time can be shortened and any spare green given to the minor road, which can then be made narrower than the above rule would suggest.

For three-leg junctions with two-phase control the widths and green times should be:

$$\frac{w_1}{w_2} = \sqrt{\frac{q_1}{2q_2}} \quad \text{and} \quad \frac{g_1}{g_2} = \sqrt{\frac{2q_1}{q_2}}$$

where the suffix $_2$ refers to the stem of the T junction. Thus, a major road through a T junction carrying four times as much traffic as the stem should have a width 1.4 times that of the stem, a length of widening 2.8 times and a green period 2.8 times as long as that of the stem.

Calculations should cover morning, evening and other peaks to determine the predominant flows at different times of the day. The width required for any approach not considered may be determined from the green time allotted to its phase. In deciding the values of q_1 and q_2 for substitution in the above formula, right-turning vehicles if few in number should be taken as equivalent to 1¾ straight-ahead vehicles. If they are so numerous as to require special right-turn lanes they should be subtracted from the flow q_1 or q_2 before determining the ratios of the remaining approach widths.

This method minimizes the total width of the approaches for a given capacity. It has the following advantages:

(i) greater convenience for pedestrians crossing the road;
(ii) reduced clearance distances and all-red times;
(iii) reduced encroachment on frontage development and footways.

Where uniform widening of an approach is prevented by the presence of existing buildings it may only be possible to flare the approach. On dual-carriageway roads extra width may sometimes be obtained by reducing the width of the central reserve, but it should not be less than 4 ft. Although the final layout may be influenced to some extent by property acquisition difficulties or costs, it should always have regard to the integral number of lanes needed for through and turning traffic.

11.6.3 Traffic lanes

Approach widths may be estimated initially as recommended in Sub-Section 11.6.2 but may need to be adjusted to provide an appropriate integral number of lanes for straight-through and turning traffic, having regard to the overall width available. Where the approach width is less than 17 ft. no lane markings should be provided; for widths between 17 and 25 ft. the approach should be marked as two lanes; for widths between 25 ft. 6 in. and 27 ft. the approach should be marked as either two or three lanes, depending on the traffic movements required; for widths over 27 ft. the approach should be marked as three lanes. Lane widths need not all be the same and should be chosen with regard to the volume and type of traffic using each lane.

Lane widths of 10 ft. will often be suitable for new or improved junctions, but 11 or 12 ft. lanes may be warranted where traffic includes a high proportion of commercial vehicles. At restricted sites 8 ft. 6 in. lanes may have to be accepted. Nearside lanes up to 14 ft. wide may be useful where there are many bicycles.

The number of lanes on any exit from an intersection should normally be the same as the number of lanes for straight-through traffic on the approach, i.e. excluding any lanes provided solely for turning traffic. If it is necessary or desirable to reduce the width of the exit by one lane the reduction should be made by means of a taper at least 300 ft. long.

Special lanes should be provided where necessary for right- or left-turning traffic. Turning lanes should be so aligned and marked that they do not entrap through traffic. Obstruction of nearside lanes by parked vehicles or bus stops should not be permitted.

11.6.4 Carriageway markings

The provision of lane lines and arrow markings on the approaches to traffic signals will enable drivers to select the required route and will promote the orderly flow of traffic. Carriageway markings and direction signs should be located sufficiently far in advance of the junction to enable drivers to select the required lane before joining the queue of waiting vehicles.

Proposals to reserve particular traffic lanes exclusively for turning traffic require careful consideration. Unless the volumes per lane of straight-through and left-turning traffic are approximately equal the capacity of a junction would be reduced by reserving a lane for the left turn. Provision of an additional lane for right-turning traffic is desirable, but if space does not permit this the off-side approach lane should only be reserved for the turn if turning vehicles are sufficiently numerous to constitute a major obstruction to straight-through traffic.

11.6.5 Division of carriageways

In many cases, such as at Y junctions where traffic divides fairly evenly to forking roads, the centre line of the approach road may advantageously be offset so as to allow more lanes into the junction, as shown in Diagram (1) of Fig. 11–3.

In Diagram (2) the layout has been adjusted to take advantage of the three-lane width of the left fork so as to minimise the proportion of cycle time required for Phase 2.

Similarly, on the stem of a T junction the approach can advantageously be made one lane wider than the exit into the stem, as shown in Diagram (3).

Side roads often require a high proportion of the cycle time, and it may prove beneficial to widen them so that they require only a short phase to clear their traffic. This arrangement may increase the capacity of the major road by as much as 50% and is particularly useful where it is impracticable to widen it because of property acquisition or other difficulties. The rule given in Sub-Section 11.6.2 for a cross-road junction allows more width to the side road in relation to its flow than to the main road; for T junctions the rule favours the side road even more.

11.6.6 Siting of traffic signals

As signal control involves the timed separation of traffic conflicts it is essential that traffic signals should be clearly visible. The standard layout shown in Diagram (1) of Fig. 11–4 should form the general basis for designing new installations and modifying existing ones.

A primary signal is sited on the nearside of each approach close to the junction, and the carriageway is marked with a stop line about 3 ft. before the signal. A secondary signal giving the same indication is normally sited on the offside of the road beyond the junction. On roads with refuges or a central reserve the primary signal should be supplemented by a second primary signal on the refuge or reserve, and the secondary signal should be sited on the further refuge or reserve instead of on the offside of the road if it will then be more conspicuous to traffic. The secondary signal should be sited within an angle bounded by the centre line of the carriageway extended through the junction and a line 30° to the right of it, drawn from the intersection of the stop line and the centre line.

A typical signal layout for a junction with an early cut-off feature is shown in Diagram (2). The cut-off occurs on approach A so as to allow a heavy right turn from approach B, which has been widened to accommodate a turning lane by slightly off-setting the refuge.

As in Diagram (1) the secondary signal for approach B may still be sited on the opposite approach refuge, even though this will be somewhat to the left of the refuge on approach B. But the secondary signal for approach A is best sited on the far end of the adjoining refuge; this is to ensure that drivers waiting to turn right from A and pedestrians wishing to cross approach A are not misled into thinking the phase has ended by seeing a red signal in the normal secondary position.

The provision of a right-turn green arrow on the secondary signal for approach B (illuminated during the early cut-off period) will minimise delay and make the turn safer.

It will be noted that a channelising island has been provided in the wide mouth of approach C. This enables the traffic signals and the stop line to be brought close to the junction, thereby reducing the time required to clear the junction. Similarly the kerb on approach A has been realigned to improve the positioning of the stop line, but still ensures an easy turn from A to C.

11.6.7 Crossroad layouts for right-turning traffic

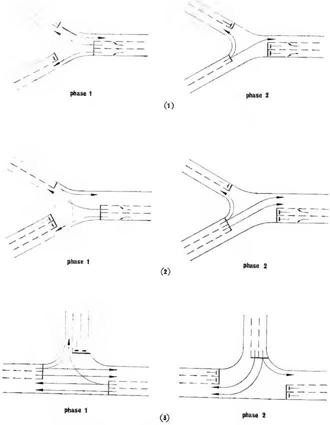
Opposing right-turning vehicles can turn either on the offside of each other or on the nearside. In the former case they have good visibility and can see an approaching gap in the opposing stream in which to complete their turn. But if there are too many turning vehicles from the two directions for the storage space within the intersection the two streams will interlock, with consequent congestion and delay. With the nearside method locking cannot occur, but visibility is often restricted and drivers may have to wait until the end of the green period before turning in order to be sure that there is no opposing straight-through traffic.

To overcome the visibility problem and preserve the advantage of nearside turning the layouts shown in Fig. 11–5 may be used. In Diagram (1) the central reserve is offset to provide additional lanes for turning traffic and better visibility from the stopped position. A further improvement in visibility and better placing of turning vehicles may be obtained as shown in Diagram (2) by widening the major road sufficiently for the turning lanes to be separated from the through traffic lanes by additional channelising islands.

If there is a preponderance of right-turners from one approach, early cut-off or late-start features should be provided, but if there are many right-turners from both approaches a separate phase may be needed in conjunction with the nearside method of turning.

If the volume of right-turning traffic is large enough to require double turning lanes the turning traffic should always be signalled separately and should move only on its own phase.

Lane and arrow markings should be provided as shown for the guidance of drivers.



note : arrows indicate direction of traffic, not carriageway markings

Fig. II-3 Division of carriageways

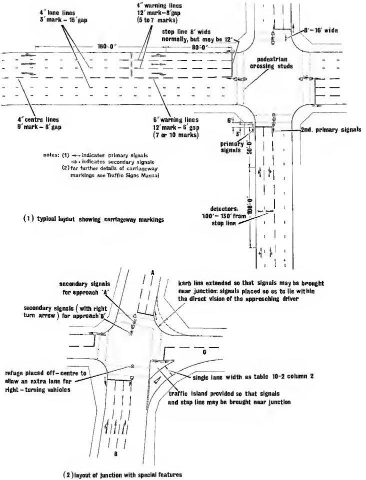


Fig. 11-4 Layouts for signal-controlled junctions

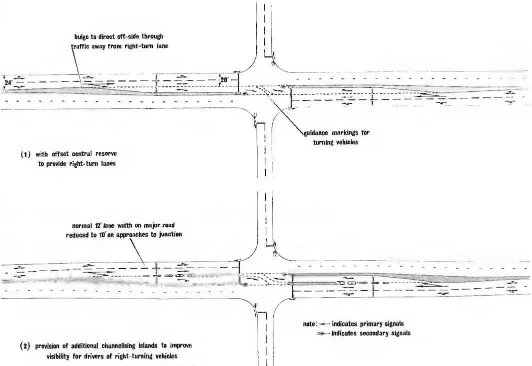


Fig. 11–5 Arrangements for nearside turning at signal-controlled junctions

Junction with double right-turn lanes

12 Roundabouts

Some of the circumstances which may favour provision of a roundabout instead of traffic signals are:

(i) a high proportion of right-turning traffic at the junction (at a four-leg junction a roundabout may need less land than traffic signals if right-turning traffic exceeds about 30% of all approaching traffic);
(ii) the existence of more than four approaches to the junction;
(iii) approach widths so restricted that it would be impracticable to provide separate lanes for through and turning traffic;
(iv) other junctions so near that there would be insufficient space for the formation of queues;
(v) a Y junction layout lending itself to roundabout design.

At sites where control by roundabout or traffic signals is equally feasible, a roundabout may be safer and less restrictive.

For further guidance on the choice between traffic signals and roundabouts reference should be made to the paper by Messrs. Webster and Newby published in the January 1964 Proceedings of the Institution of Civil Engineers.[26]

12.1 Capacity

Practical capacities of weaving sections may be calculated from the formula given below or determined from the nomogram in Fig. 12–1. The roundabout dimensions referred to in the formula are shown in Diagram (1) of Fig. 12–2 together with the entry, exit and internal angles.

$$Q_p = \frac{86w\left(1+\frac{e}{w}\right)\left(1-\frac{p}{3}\right)}{1+\frac{w}{l}}$$

where Q_p is the practical capacity of the weaving section in pcu's per hour (for roundabout design values see Table 1–3);
w is the width of weaving section in feet (within range 20 to 60 ft.);
e is the average width in feet of the two carriageways e_1 and e_2 entering the weaving section ($\frac{e}{w}$ range 0.4 to 1.0);
l is the length of the weaving section in feet (range 60 to 300 ft. and $\frac{w}{l}$ range 0.12 to 0.4);
p is the proportion of weaving traffic, i.e. the ratio of the sum of the weaving streams to the total traffic on the weaving section (range 0.4 to 1.0).

The practical capacity derived from this formula is 80% of the maximum capacity found in experiments on isolated weaving sections. This provides a margin of safety to meet the effects of wet weather, possible interaction between weaving sections, variations in flow over the hour and possible interference due to pedestrians crossing the road. The ranges quoted may not be absolute ranges, but are those covered by tests; the formula is valid within these ranges provided there are no standing vehicles on the approaches to the roundabout and the site of the roundabout is level, with approach gradients not exceeding 1 in 25.

Where the layout is not conducive to uniform speeds the following arbitrary adjustments to capacity may be made:

(i) where the entry angle is between 0° and 15° deduct 5% from the capacity of the weaving section;
(ii) where the entry angle is between 15° and 30° deduct 2½% from the capacity of the weaving section;
(iii) where the exit angle is between 60° and 75° deduct 2½% from the capacity of the weaving section;
(iv) where the exit angle is greater than 75° deduct 5% from the capacity of the weaving section;
(v) where the internal angle is greater than 95° deduct 5% from the capacity of the weaving section.

Where the pedestrian flow across an exit from the roundabout exceeds 300 per hour an arbitrary reduction of one-sixth should be made in the practical capacity of the preceding weaving section.

As roundabouts have a tendency to lock when overloaded and do not readily recommence functioning it is important that they should have adequate reserve capacity to meet future peak flows and that attempts should be made to reduce the chances of locking. One method which has given promising results is to erect signs requiring approaching traffic to give way to that already on the roundabout. Where this has been done experimentally, locking has virtually been eliminated and capacity flows have been maintained even in overloaded conditions. Delays have been reduced owing to the increased capacity, which has ranged from 6 to 14% above that obtainable with police control. The accident rate has been reduced by more than 40%.

An alternative method of dealing with roundabouts which are prone to locking in peak periods is to install traffic signals on the approaches. In the case of two simple four-leg roundabouts the capacity was increased by about 10% over that obtainable with police control, and there is some evidence of a further improvement as drivers have become accustomed to this type of control. With two more complicated roundabouts, with six legs, no measurable improvement over police control was found.

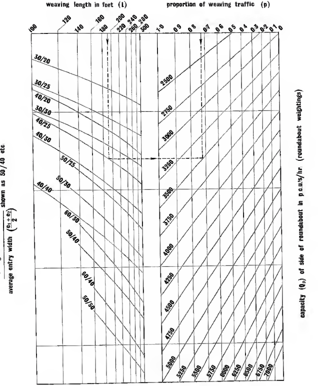
Signals did not always prevent locking of the roundabouts, but by using them in conjunction with a newly developed presence detector (now commercially available) which automatically adjusts the clearance period during each cycle to fit the traffic requirements locking was virtually eliminated.

12.2 Roundabout design

12.2.1 Shape of the central island

Simple geometric figures such as the circle or ellipse may not be the most suitable where the angles between the approach roads are irregular and the site is constricted. Asymmetric shapes, either wholly curved or with a combination of straights and curves (as shown in Diagrams (1) and (5) of Fig 12–2) will often provide the only satisfactory solution.

Where two roads cross at or nearly at right angles the central island is usually round or square with rounded corners, as



To determine the capacity of the side of a roundabout, use the left-hand diagram to obtain the point corresponding to the weaving length, weaving width and average entry width (interpolating where necessary), extend a line horizontally to the right-hand diagram, from which the capacity is given for the proportion of weaving traffic.

To determine the dimensions of a side of a roundabout, use the right-hand diagram to obtain a point corresponding to capacity and proportion of weaving traffic and draw a line horizontally to the left-hand diagram. This line will cut various alternatives of weaving length, weaving width and entry width, from which a suitable design may be obtained.

Example shown:

$l=190'$ $w=40'$ $e=25'$

$p=0.73$ $Q_p=3500$ pcu's/hour

Fig. 12-1 Roundabout design chart

illustrated in Diagrams (2) and (3). The corners of a square island should be adequately rounded off, with a corner radius of at least 60 ft. The elongated central island shown in (4) will be appropriate for a scissors junction. For some junctions, particularly those with more than four approaches, irregularly shaped roundabouts may be required (5). It will be noted that in these designs there are no 'dead' areas of carriageway on the periphery of the roundabout, as shown by cross-hatching in Diagram (6). Such areas are rarely used by traffic and contribute little to the capacity of the weaving sections; they should therefore be avoided in design.

Gyratory systems with exceptionally large central islands are sometimes formed from existing streets and may surround buildings or development (7). In such cases the shape of the central island will probably be less important than the adequacy of the weaving sections.

Street lighting columns and traffic signs on the central island and the periphery of a roundabout should desirably be sited where there is little risk of their being hit by out-of-control vehicles. To minimise danger to vehicles, kerbing around the central island should not be high; splay kerbs are preferable to vertical kerbs.

12.2.2 Entry and exit layouts

A pedestrian refuge or channelising island is usually sited on each approach to a roundabout to assist pedestrians and guide traffic into the weaving section at a suitable angle. Merging manoeuvres can be made easier by confining entering vehicles to definite paths. To achieve this the channelising islands should be made as large as possible without encroaching on the desired paths of vehicles.

To achieve smoothness of flow the entrance radii should be similar to or slightly less than those of the central island. Entrance radii of between 40 and 75 ft. will usually be suitable for urban designs, the smaller dimensions being used approaching short weaving lengths or where space is restricted. A slight dominance can usefully be given to the flow around the central island by making its radius or radii slightly greater than the entry radii, with a minimum of 60 ft. To assist the clearance of traffic from the roundabout the exit radii should be greater than those of the entrances and central island. A tangential alignment may sometimes be adopted, as shown for the exit marked A in Diagram (1) of Fig. 12–2. Where, however, pedestrian flows across the exit roads are heavy, radii similar to those at the entrances should be provided to keep exit speeds reasonably low.

Where possible, layouts should not include sharp exit angles, obtuse internal angles around the roundabout and tangential entrances to the weaving sections. If these undesirable features cannot be avoided the capacity of the weaving sections should be adjusted as indicated in Section 12.1.

12.2.3 Weaving sections

On roundabouts in rural areas, weaving widths are normally about 30 ft., but in urban areas designs are less standardised, perhaps because achievement of the required capacity within the space available is more of a problem, and widths range from 24 ft. up to about 60 ft.

A study of over 400 weaving sections on existing roundabouts shows that mean $\frac{l}{w}$ ratios range from 3.4 in town centres (where land tends to be scarce and speeds are fairly low) to 3.9 in the suburbs and to 4.8 in rural areas (where land is more readily available and speeds are higher). When designing a roundabout it may be useful as a first step to calculate the weaving width required for an appropriate $\frac{l}{w}$ ratio. If $\frac{l}{w}$ is denoted by r and $\frac{e}{w}$ is taken as unity, w can readily be estimated from a rearranged version of the formula in Section 12.1:

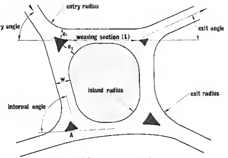
$$w = \frac{\left(1 + \frac{1}{r}\right) Q_p}{172\left(1 - \frac{p}{3}\right)}$$

This will enable a suitable standard width to be chosen for the weaving section (which should be greater than that of the approach carriageway) and the weaving length can then be calculated from the assumed $\frac{l}{w}$ ratio.

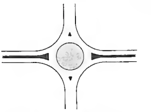
12.2.4 Pedestrians

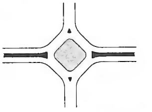
Pedestrian crossings of the zebra type are frequently sited at the entrances and exits of roundabouts. Although subways would often be safer and cause less delay to traffic, the presence of pedestrian crossings on the approach carriageways is unlikely to have an adverse effect on the operation of the roundabout. On the other hand, zebra crossings on the exit carriageways may delay vehicles and cause a queue to extend back into the roundabout, thereby increasing the risk of locking. Sometimes that part of the crossing on the exit carriageway can usefully be sited further from the roundabout, provided this does not unduly inconvenience pedestrians. Guard rails should be erected where necessary to guide pedestrians to suitable crossing points and to discourage crossing via the central island.

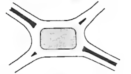
The provision of grade separation for pedestrians (and possibly cyclists) will sometimes be warranted to enable them to negotiate the junction safely and without delaying other traffic.

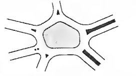


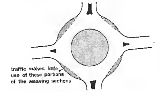
(1) roundabout dimensions


(2) circular central island at normal 90° crossroads

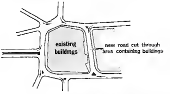

(3) square central island at normal 90° crossroads


(4) roundabout at a scissors-type intersection


(5) complex intersection with many approaches



(6) with this layout the weaving section is partly wasted



(7) gyratory system formed mainly from existing streets

Fig. 12-2 Roundabout layouts

13 Interchanges

Interchanges are junctions with grade separation and will normally be appropriate on urban motorways and at more important junctions on all-purpose *primary distributors*.

To justify the high cost of grade separation there must be appropriate benefits such as increased capacity, less delay, fewer accidents and reduced operating costs. In view of the restricted space available in urban areas and the high cost of interchanges it is particularly important that designs should be adequate for long-term traffic requirements. Interchanges are large and often conspicuous; as far as possible, designs should be chosen to minimise any adverse effect on amenity. Designs should be as compact as possible to reduce delays to vehicles changing from one road to another, but curves should not be so tight as to be dangerous.

13.1 Capacity

13.1.1 Through carriageways

The practical capacity of through lanes 11 or 12 ft. wide should be taken as 1,500 pcu's per hour. Capacity should be reduced by 10% where lane widths of only 10 ft. can be obtained.

13.1.2 Slip roads

Slip roads form the link between one major road and another at an interchange. As their gradients and curvature are likely to be less favourable than those of the major roads their practical capacity will be lower and should normally be taken as 1,200 pcu's per lane per hour. As the traffic flow on slip roads may depend on the capacity of their junctions with the major roads it is important that designs should be properly balanced.

13.1.3 Merging traffic

Unless an extra lane is provided on the major road beyond an entry fork, the volume of traffic joining from a slip road and acceleration lane cannot exceed the capacity of the gaps in the nearside traffic stream. American experience[25] suggests that in peak conditions maximum merging flows (flow on nearside lane upstream of fork plus that from slip road) may range from about 1,300 to 2,000 vehicles per hour. Fig. 13–1 has been derived from observations in the United States and indicates how entry volumes (shown as 90% maximum) are likely to be affected by flows on the major road approaching the entry fork. If the merging capacity is inadequate an additional lane will be required on the major road beyond the fork.

If there is an exit fork a short distance downstream from the junction, vehicles intending to turn off may so increase the volume of traffic on the nearside lane that the entry flow may be seriously reduced unless an auxiliary lane can be provided between the entry and exit slip roads. This length of the major road will need to be checked for adequacy as a weaving section as indicated in Sub-Section 13.1.5.

13.1.4 Deceleration lanes

The capacity of a single-lane exit may be taken as about 1,200 pcu's per hour provided the deceleration lane is well designed and the exit is clearly signposted well in advance of the junction.

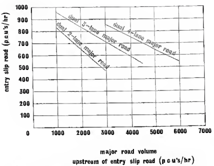
13.1.5 Weaving sections

Weaving manoeuvres are required not only at roundabouts but at interchanges such as the cloverleaf and on motorways between successive entry and exit slip roads. It is important that designs should be checked to ensure that the widths and lengths of all such weaving sections are adequate.

The dimensions and capacities of weaving sections on roundabouts are considered in Section 12.1. Suggested minimum lengths for longer weaving sections (allowing weaving at about 30 mph as required on urban motorways) are given in Table 13–1, which is based on American experience.[25] Where weaving takes

Proposal for a multi-level interchange at Gravelly Hill, Birmingham

Fig. 13–1 Merging flows



place on slip roads instead of on the motorway, speeds will be lower and the weaving lengths may be halved.

Table 13–1 Weaving lengths

Weaving volume pcu's per hour	Minimum length of weaving section ft.
1,000	250
1,500	400
2,000	650
2,500	950
3,000	1,350
3,500	1,850

The number of lanes required for minimum weaving sections may be estimated from the formula given below. To allow for mixed traffic, hourly flows should be given in urban pcu's (see Table 1–3).

$$N = \frac{W_1 + 3W_2 + F_1 + F_2}{C}$$

where N is the number of lanes;
W_1 is the larger weaving flow;
W_2 is the smaller weaving flow;
F_1 and F_2 are outer non-weaving streams,
C is the normal lane capacity of the major road.

When N is less than 3 for a total flow with an outer stream exceeding 600 pcu's per hour, an additional lane should be provided for the outer stream. Similarly, when N is less than 4 for a total flow with two outer streams each exceeding 600 pcu's per hour, an additional lane should be provided for each. If separate provision is made for outer streams they should be omitted from the formula when calculating the remaining number of lanes.

Where a longer weaving length than that indicated can be provided it may be possible to reduce the width required. The formula for the number of lanes should be adjusted by substituting the following expression for the term $3W_2$:

$$\left(\frac{2 \times \text{length given in table}}{\text{actual length}} + 1\right) W_2$$

Doubling the length would reduce $3W_2$ to $2W_2$; tripling the length would reduce it to $1.7\, W_2$. A useful graph for calculating the width of long weaving sections is given in *Urban Traffic Engineering Techniques*.[7]

If the exit slip road is far enough ahead of the entry slip road the width of the major carriageway in between may be calculated in the normal manner, without regard to weaving. There is little evidence on which to assess the minimum length required, but American experience[8] suggests that the distance in feet should be between two and three times the hourly weaving volume in vehicles per hour, the higher values being appropriate for large weaving volumes.

13.1.6 Lane balance and location

At each entry and exit fork the number of lanes provided on the major road and slip road should have regard to the future peak flows to be accommodated, in accordance with the recommendations on lane, merging and weaving capacities given in the preceding sub-sections.

Where there are a number of entry and exit forks in proximity, as at an interchange, it may be desirable to increase the number of lanes beyond the minimum indicated by the capacity calculations in order to ensure efficient operation and easy movement from one carriageway to another. The number of lanes provided should have regard to the following practical considerations.

(i) Where two traffic streams merge, the number of lanes beyond the fork should not be less than the sum of the lanes on the merging carriageways minus one. For example, beyond the junction of a two-lane slip road with a three-lane carriageway the number of lanes should be at least four.

(ii) Where an exit slip road requires two lanes, the number of lanes on the major carriageway may be reduced by one, provided the number remaining is at least two.

(iii) The width of the major carriageway should not be reduced by more than one lane immediately beyond an exit fork.

The distance between successive exit forks or entry forks should be at least the length of the intervening speed-change lane and should be increased as necessary to facilitate manoeuvring and signposting. Where an exit fork is located shortly after an entrance fork, weaving will take place in between and the length should be as indicated in Table 13–1, with a desirable minimum of 600 ft. Where an entrance fork is located after an exit fork on the same side of the road the design of the slip roads will usually require a length of about 600 ft. between the forks.

13.2 Acceleration and deceleration lanes

Acceleration and deceleration lanes should be provided where slip roads join an urban motorway and may also be useful at important junctions on other roads. Direct-taper layouts, as shown in Diagram (1) of Fig. 13–2 will normally be appropriate for speed-change lanes and will suit the natural path of vehicles.

Speed-change lanes should be long enough to ensure ample space for merging and diverging manoeuvres. At the end of an acceleration lane there should be no kerb or other obstruction which might be dangerous for a driver unable to merge with the traffic stream on the nearside lane. The angle between the slip roads and the through carriageways should neither be so large that vehicles enter or leave the main road too abruptly nor so small that the nose is unduly long and the length available for merging or diverging is reduced. Nose angles of about 4 to 5° (i.e. tapers of 1 in 12 to 1 in 15) should usually be suitable for urban conditions; a gradual approach from the entry slip road is particularly important to ensure good visibility and smooth merging. Where possible the entry and exit noses should be at least 150 ft. long; adjoining the nose, slip roads should be straight and approximately at the same level as the through carriageways.

Speed-change lanes are best located where the major road is reasonably straight and level and visibility standards are high. They should be carefully sited to ensure that they are not hidden from the view of approaching traffic by horizontal or vertical curves. Exits on tangent alignments on the outside of a curve, as shown in (2), may be confusing to drivers and if the deceleration lane cannot be resited away from the curve it should be designed so that a definite change of course is required on leaving the major road (3). Entrances on tangent alignments are equally undesirable, and layouts should encourage full use of the acceleration lane and avoid abrupt entry on to the major road.

Where it is required to reduce the width of the major road by one lane after an exit fork the reduction should usually be made by means of a taper at least 300 ft. long beyond the exit nose (4). This arrangement is preferable to an immediate reduction at the nose, which might entrap through traffic on to the exit slip road.

Table 13–2 Acceleration and deceleration lane lengths

Design speed of major road	Gradient of major road	Acceleration lane length	Deceleration lane length
mph	%	ft.	ft.
50	4% up	800	270
	level	560	300
	4% down	440	340
40	4% up	510	250
	level	340	
	4% down	250	
30	4% up	210	210
	level		
	4% down		

The lengths of acceleration lanes are particularly influenced by adverse gradients, and wherever possible they should be sited where gradients on the major road are favourable. If there are uphill gradients on the entry slip road and the major road, heavy vehicles may be unable to exceed the crawl speed and drivers may experience difficulty in joining the nearside traffic stream. If the road has paved verges they may be able to proceed along the verge until a suitable gap in the traffic occurs, but where there is no verge it may be necessary to provide an additional lane on the rising gradient.

Recommended minimum lengths for deceleration and acceleration lanes in high-volume urban conditions are given in Table 13–2. These are the lengths adjoining and open to the through carriageways; they assume a nose length of 150 ft. and should be increased as necessary if the nose is shorter.

The lengths given in the table will be suitable both for acceleration or deceleration at ordinary interchanges and for merging or diverging manoeuvres at major interchanges between motorways.

13.3 Slip roads

Slip roads may either be straight, slightly curved or looped, depending on the layout of the junction. At important junctions with both direct and loop connections the major traffic streams should if possible be routed via the direct connections. Recommended design standards for slip roads are given below:

(i) Design speed — This should normally be between two-thirds and half that of the more important major road at the junction. For loop slip roads a lower standard may have to be adopted where space is restricted; 15 mph should be regarded as the usual minimum.

(ii) Width — Slip road carriageways should normally carry one-way traffic only. One-lane slip roads should have a 14 ft. carriageway bounded on the left-hand side by a 1 ft. marginal strip or lip kerb and a paved verge not less than 5 ft. wide and on the right-hand side by a raised kerb and a verge wide enough to give clearances as indicated in Table 4–2.
Where traffic flows warrant the provision of two-lane slip roads, the carriageway width should be increased to 24 ft. Carriageways should be widened on bends as indicated in Table 10–2.

(iii) Curve radii — Minimum radii for various design speeds are given in the second column of Table 13–3.

(iv) Sight distances — Minimum stopping distances for various design speeds are given in the third column of Table 13–3. Stopping distances should be checked between points 3 ft. 6 in. above the carriageway along lines 6 ft. from both the nearside and offside edges of the carriageway.

(v) Gradients — Slip road gradients should preferably not exceed 5% and should nowhere be steeper than 8%. Where a slip road carries a large volume of heavy commercial traffic its gradient should desirably be limited to 4%.

Table 13–3 Minimum slip road radii and stopping distances

Design speed	Minimum radius	Minimum stopping sight distance
mph	ft.	ft.
40	490	300
30	240	190
25	170	150
20	110	110
15	60	70

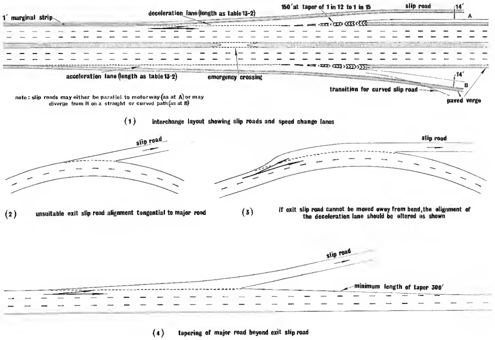


Fig. 13-2 Acceleration and deceleration lanes

Short slip roads have limited storage capacity and a temporary delay at the exit may cause traffic to back up sufficiently to block the entrance. Longer slip roads are likely to function more smoothly, but if they are very long two-lane carriageways may be needed to avoid delays due to slow-moving vehicles. The two-lane layout should be reduced to single lane before the slip road joins the motorway unless the full width is needed to ensure sufficient capacity at the entrance or exit.

Where the slip road joins the all-purpose road, junction design and visibility standards appropriate to the all-purpose road should be used.

The possible need for road heating on slip roads should be considered. Avoidance of snow and ice hazards is particularly important on steep or sharply curved slip roads.

13.4 Interchanges between *Primary* and *District distributors*

The three basic types of interchange between *primary* and *district distributors* are the diamond, the grade-separated roundabout and the partial cloverleaf. These are illustrated in Diagrams (1), (2) and (3) respectively of Fig. 13–3.

Where space is restricted and land costs are high, the diamond interchange with traffic signal control where the slip roads join the all-purpose road is probably the most useful type. With linked traffic signals and adequate storage for vehicles awaiting the green signal these interchanges function smoothly and can cope with high turning volumes.

Where two parallel cross-streets are available as connections to the *primary distributor* the split diamond layout shown in (4) can be used. This layout is more efficient than the conventional diamond; traffic conflicts are reduced and fewer lanes are likely to be required. Two-phase signal control can be used instead of the three-phase control needed for the conventional layout. The most effective layout is that shown in (5), where the slip roads are linked to one-way cross-streets. With two-phase signals and one-way streets this arrangement gives the highest capacity and the least delays.

The grade-separated roundabout requires the construction of two bridges and generally needs more land than the diamond layout. It may be useful where a number of streets intersect at the interchange and in suburban areas where land values are not so high. Both the diamond and the grade-separated roundabout layouts have the advantage of embodying straight or gently curved slip roads with a substantial distance between deceleration and acceleration lanes. Where, however, the *district distributor* carries a large volume of traffic it may be impossible to provide sufficient capacity on the weaving sections of the roundabout without excessive use of land. One method of overcoming this difficulty is to provide a three-level interchange with the roundabout between the *primary* and *district distributors* and used only by interchange traffic. In view of the probable high cost of this solution it may only be practicable in special cases.

The partial cloverleaf design requires more land than the others and has sharply curved slip roads. In view of the space required for the loops it cannot be linked so easily to collector-distributor or frontage roads parallel to the *primary distributor*. Where there is an obstruction such as a railway or river immediately to one side of the *district distributor* the layout can be amended as shown in (6). This layout affords no choice of quadrants for the location of the slip roads; where a choice exists it may sometimes be possible to minimise right-turning movements at the junctions of the slip roads and the *district distributor* by

Gantry sign at exit slip road from Motorway M 4

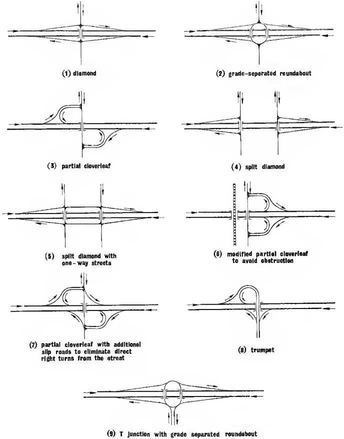


Fig. 13–3 Interchanges between *primary* and *district distributors*

Cumberland Basin swing bridge and interchanges, Bristol docks (*reproduced by courtesy of the Bristol City Council*)

locating the slip roads in the appropriate quadrants. If the conventional diamond layout does not have sufficient capacity and the split diamond cannot be used, the special partial clover-leaf layout shown in (7) may be useful. This layout can accept large traffic volumes; the additional slip roads eliminate direct right turns from the *district distributor*.

Where the *district distributor* forms a T or Y junction with the *primary distributor* a trumpet layout (8) or modified grade-separated roundabout (9) may be used. If the traffic volumes on the direct and loop slip roads of the trumpet differ appreciably it should preferably be aligned so that the higher volume will use the direct connection.

13.5 Three-leg interchanges between *Primary distributors*

Interchanges between *primary distributors* should be designed to allow for the continuous movement of traffic between one road and the other. Some designs require loop slip roads; some involve weaving either on the slip roads or on the *primary distributors*; some require two exits instead of one from each approach. Designs with loop slip roads should preferably be arranged so that major turning movements take place on direct or semi-direct connections. Designs which require weaving on the *primary distributors* are undesirable; the inclusion of weaving sections may limit the capacity of the junction, but if they have to be accepted weaving should take place on the slip roads and not on the through roads. Designs needing two exits from the *primary distributor* require some drivers to make two decisions within a short space of time and to position their vehicles accordingly. The signposting of such junctions will require special care.

Some typical designs for three-leg interchanges are shown in Fig. 13-4. In Designs (1), (2) and (3) the roads cross at only two levels and only a single bridge is required; Design (3) does not allow for all turning movements but may sometimes be acceptable. Design (4) is compact, but its usefulness and capacity may be limited by the need for a weaving section on the slip roads. Design (5) has no weaving section but is less compact than (4) and has sharp curves on its jug-handle slip roads. Designs (6), (7), (8) and (9) are particularly suitable for high-volume interchanges; (6) and (7) each require three bridges, but (8) and (9) are made more compact by using a single three-level bridge. None of these designs requires more than one exit on each approach and only one embodies a weaving section. It will often be useful to extend the stem of the T, as shown by the dotted lines in Diagrams (4) and (7); this will provide direct access between north and south, but without interchange facilities for traffic from the north.

The forks where traffic streams merge or diverge should be designed in a similar manner to conventional speed-change lanes, with lengths appropriate to the design speed of the major roads or slip roads and preferably with the traffic entering or leaving the major streams from the left.

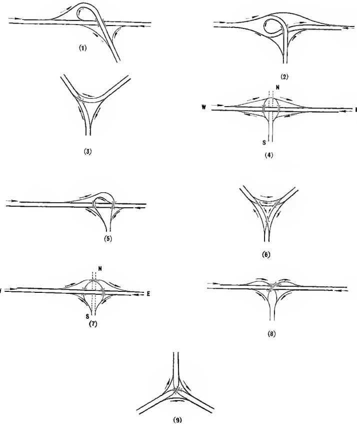


Fig. 13–4 Three-leg interchanges between *primary distributors*

13.6 Four-leg interchanges between *Primary distributors*

Some typical designs for four-leg interchanges are shown in Fig. 13–5. The cloverleaf designs (1) to (4) all have slip road loops and involve weaving. Design (2) is preferable to (1) as the weaving operations are transferred from the *primary distributors* to the slip roads and there is only one exit on each approach instead of two. Design (3) is a modified version allowing a major turning movement from south to east without requiring a loop slip road. The design can be further modified as shown in (4) to allow easier right turns from, say, south to east and north to west. Only one two-level bridge is required for Designs (1) and (2), but Design (3) has three bridges and Design (4) has four.

Design (5) has two exit slip roads on each approach; it is reasonably compact and does not involve weaving, but needs five bridges—four of them wide enough to accommodate a deceleration lane as well as dual carriageways. In Design (6) the through roads cross above and below a conventional roundabout which is used by turning traffic; this design requires five two-level bridges but can be made fairly compact provided the weaving volumes on the roundabout are not too large. Design (7) has the advantage of having no loops or weaving lengths, but requires separation of the through carriageways and eight two-level bridges and involves some joining and leaving movements on the right. Design (8) is reasonably straightforward and compact; it requires no loops or weaving but involves the construction of a central four-level structure.

There are many other four-leg interchange patterns; all will be expensive and the choice will usually lie in the design which suits the site and can handle the required traffic movements with the least possible complexity and cost. The signposting of junctions requiring two exits on each approach will need particular care. Designs requiring entrances or exits on the right-hand side of the road should preferably not be used.

Four-leg interchanges are invariably more complex than three-leg interchanges and are likely to be more costly and to require more land. It may sometimes be advantageous to design the primary network to avoid or limit the need for four-leg interchanges. Alternatively it may be possible to simplify some designs by reducing the number of turning movements.

13.7 Spacing of interchanges

As shown in Diagram (1) of Fig. 13–6, the minimum spacing between diamond interchanges will be about 1,800 ft. This allows a weaving length of 600 ft. between successive entry and exit slip roads, which will each need to be at least 600 ft. long. The 600 ft. weaving length will serve as a combined acceleration and deceleration lane and, as indicated in Table 13–1, will have a weaving capacity of nearly 2,000 pcu's per hour.

Although the spacing between urban interchanges may be as little as 1,800 ft. it should desirably be at least half a mile. This will ensure better designs with longer weaving lengths, easier slip road gradients and improved capacity. Where necessary the spacing should be increased to provide the required weaving capacity.

Where a major interchange (i.e. between two motorways) follows an entry slip road or precedes an exit slip road it is particularly important that sufficient distance should be allowed for weaving. Where possible the distance should be twice that indicated in Table 13–1, with a minimum of about 1,200 ft.; this will allow weaving to take place at about 40 mph.

Various methods of decreasing the spacing between interchanges are illustrated—in order of increasing effectiveness—in Diagrams (2) to (5). The conventional sequence of entry and exit slip roads is maintained in (2) and (5), but in (3) space is saved by grouping together two or more entry or exit slip roads. The arrangement shown in (4) permits a further saving of space by combining the grouped and criss-cross slip roads. In (5) the slip roads are at right angles to the motorway, and their junctions with the all-purpose road system must be far enough away to ensure reasonable gradients on the slip roads.

13.8 Frontage roads and collector-distributor roads

These roads are connected to the motorway system at a limited number of points but may have many connections to the street system, thereby facilitating the distribution of traffic to and the collection of traffic from busy districts such as the town centre. By reducing the frequency of access points along the main motorway they reduce weaving problems, promote free flow and preserve the high capacity of the motorway.

A frontage road system is illustrated in Diagram (1) of Fig. 13–7. The frontage roads flank the motorway; they are all-purpose, at the same level as the street system and usually one-way. They are linked to streets which might otherwise come to a dead end at the motorway. They form boundaries to environmental areas and will usually serve as *district distributors*.

Collector-distributor roads are shown in Diagrams (2), (3) and (4). They have motorway status and are grade-separated from the all-purpose street system. In Diagram (2) the collector-distributor roads flank the motorway and are at the same level; they are linked by slip roads to the streets. As a design speed of 30 mph will usually be appropriate for collector-distributor roads the lengths required for speed-change lanes and weaving will therefore be appreciably less than on the main motorway and more frequent connections can be provided to the street system. Where necessary the slip roads leading to and from collector-distributor roads may be grouped as indicated in Fig. 13–6.

In Diagram (3) the collector-distributor roads have dual carriageways and form a loop giving access to development some distance from the main motorway. In Diagram (4) the collector-distributor roads form spurs at right angles to the motorway.

Failure to provide frontage or collector-distributor roads adjoining heavily trafficked routes may lead to difficulties in the future. Without these facilities accesses may be required at such frequent intervals that, as the volume of traffic grows, the resulting weaving manoeuvres may seriously disrupt the flow of traffic on the motorway and reduce its capacity.

13.9 Consistency of layout

Where there are a number of interchanges at fairly close spacing along an urban motorway it is particularly important that entry and exit arrangements should be easily understood by drivers. Achievement of this objective will require not only good road design but also consistency of layout, carriageway marking and signposting. This will give drivers confidence and make it easier for them to identify exits and entrances in ample time to change lanes or adjust speed without inconveniencing other traffic.

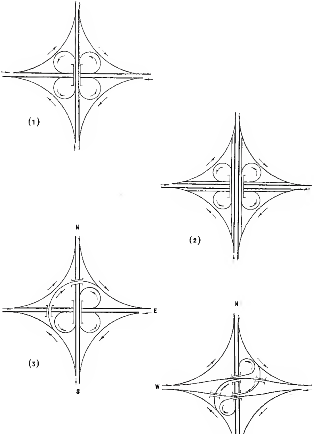


Fig. 13-5 Four-leg interchanges between *primary distributors*

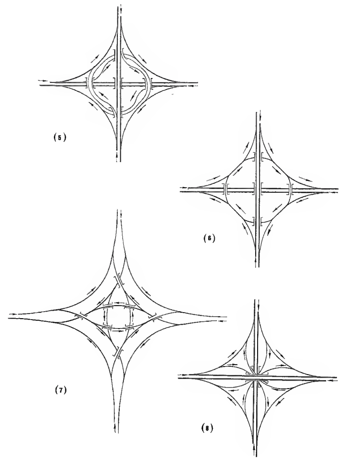


Fig. 13–5 Four-leg interchanges between *primary distributors* (*continued*)

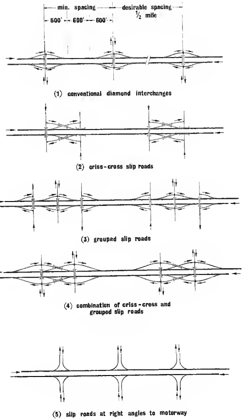


Fig. 13-6 Arrangement of slip roads at interchanges

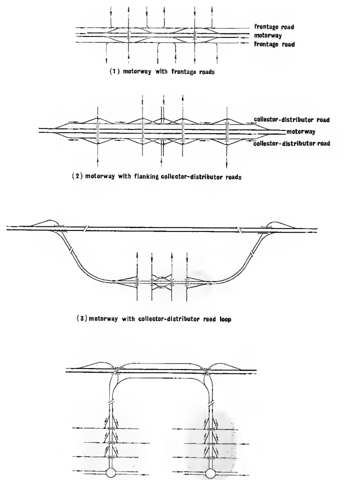


Fig. 13-7 Frontage and collector-distributor roads

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